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MEDITERRANEAN WATER SCARCITY AND DROUGHT REPORT

Technical report on water scarcity and drought management in the Mediterranean and the Water Framework Directive

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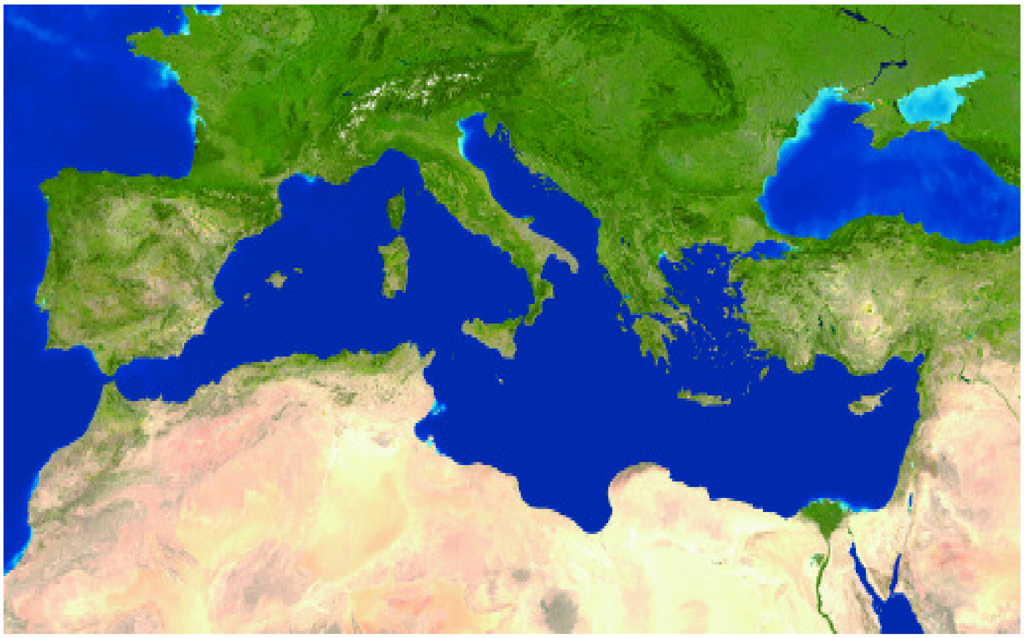

Mediterranean Water Scarcity and Drought Report

Technical report on water scarcity and drought management in the Mediterranean and the Water Framework Directive

Produced by the

MEDITERRANEAN WATER SCARCITY & DROUGHT WORKING GROUP (MED WS&D WG)

- April 2007 –

http://www.emwis.net/topics/WaterScarcity

PREFACE

As a result of the increased frequency of drought events over recent years, it was agreed at the informal meeting of Water Directors of the European Union (EU) held in Roma (Italy) in November 2003, to take an initiative on water scarcity issues. A core group led by France and Italy - the Water Scarcity drafting group of the Common Implementation Strategy of the Water Framework Directive (WFD) - prepared a technical document on drought management and long-term imbalances issues, which was presented to the EU Water Directors in June 2006. The EU Water Directors took note of the technical document and endorsed the Policy summary[1].

Water scarcity and drought was also identified by Mediterranean experts and water managers as one of the themes to be addressed in the framework of the Mediterranean – EU Water Initiative / Water Framework Directive Joint Process launched in 2004.

The first phase of this Joint Process was initiated in September 2004, thanks to a Mediterranean Workshop gathering Mediterranean Pilot River Basins from EU Member States and representatives of partner countries[2]. Three topics were selected as a first basis of common interest. Three Mediterranean thematic Working groups were set up to address these issues, including the Water Scarcity & Drought (WS&D) one. This group is led by France and the European Commission. Two Mediterranean Focal Points were invited to joint the EU group on the same issue, Egypt and Tunisia. The Focal Points participated in two workshop/conference organised in the framework of a research project: Palermo, October2004 and Cyprus, May 2005 and in EU meetings on Water scarcity held in Rome, January 2005, Paris, September 2005, Rome, October 2005 and Madrid, February 2006. Finally, a meeting of the plenary Mediterranean Working Group (WG) on WS&D was organised in Brussels on 27 September 2006, where the preparation of this report was discussed.

The Mediterranean report is based on the EU document produced in June 2006. It has been prepared by the Mediterranean WS&D WG, in the framework of the MED-EU Water Initiative / Water Framework Directive Joint Process.

The document is a technical report which consists of five parts. The introduction presents the situation of water scarcity and drought in the Mediterranean region and the linkages between the WFD and Water scarcity. In chapter I, the definitions and assessments of the different phenomena are described. Chapter II reports on planning and management of drought events. Chapter III deals with long-term imbalances in supply and demand. The conclusions and recommendations are presented in Chapter IV.
The main objective of this report is to present the Mediterranean specificities regarding water scarcity situations and droughts events and the role of the WFD. Examples of strategies and measures taken in the Mediterranean region for addressing WS&D illustrate

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[1] Water Scarcity Drafting Group – Water scarcity management in the context of the Water Framework Directive, June 2006; Report, appendix and Policy summary
http://forum.europa.eu.int/Public/irc/env/wfd/library?l=/framework_directive/scarcity_droughts/technical_report_2006&vm=detailed&sb=Title

[2] Workshop – "The PRB Mediterranean dimension", Back-to-back with the Workshop – "Linking rural development and land degradation mitigation into river basin management plans"., 22-24 September 2004 Brindisi, Italy organised by DG JRC and DG Environment of the European Commission and the Italian Ministry of Environment, APAT and the Regione Puglia

the different sections of the reports. In addition, the specificities of the WFD implementation related to WS&D are identified for non-EU countries.

Co-Authors:

Mohamed Blinda,	Plan Bleu
Mohamed Boufaroua,	Ministry of Agriculture, Tunisia
Natasha Carmi,	Palestinian Hydrologic Group, Palestine Authority
Thierry Davy,	Agences de l'eau, France
Sylvie Detoc,	European Commission, DG Environment
Jochen Froebrich,	University of Hanover, Germany (with contributions from Prof. M. Kirkby, Prof. I. Ribarova, Prof. M. G. Tournoud, Prof. P. Kondouri, Prof. E.A. Nuppenau, Dr. Huchzermeyer, Prof. R. Maja, Prof. M. Salgot, and Prof. R. Kanwar)
Dunixi Gabina,	Mediterranean Agronomic Institute of Zaragoza, Spain
Ana Iglesias,	Universidad Politécnica de Madrid, Spain
Abdul-Latif Khalid,	Palestinian Hydrologic Group, Palestine Authority
Essam Khalifa,	Ministry of Water Resources and Irrigation, Egypt
Jean Margat,	Plan Bleu
Marta Moneo,	Universidad Politécnica de Madrid, Spain
Zach Tagar,	Friends of the Earth Middle-East, Israel

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INTRODUCTION[3]

1) What is water scarcity? How is it evaluated and measured?

In general, all situations of shortage (scarcity) mean an imbalance: an excessive demand for excess compared to the supply, which is thus partly dissatisfied.

Water scarcity corresponds to the mismatch between demand (for all uses) and supply, that is to say water resources, or, more strictly, the exploitable part of resources offered by water operators; therefore water scarcity can be considered as the imbalance between water requirements and water supply.

Water scarcity can then be structural, due to the scarcity of the average resources compared to increasing demands, or random, determined by failures of natural resource (drought) or mobilization system, or because of temporary increase of demands. It can be physical, due to excessive demand compared to natural resources, or socio-economic, because of structural or random insufficiency of system means of use (poverty, defect or technical accident). It can even result from excessive demands compared to the needs.

To evaluate a water shortage situation requires defining spatial and temporal parameters and an relevant analysis of the resource system and water usage used for reference, in order to compare between resources (that is to say water production) and demand, be it for the present situation or the projected one, based on the anticipated supply and demand.

The measurement of the gravity degree of a situation of water shortage rests primarily on the difference between demand and resource, its duration and the extent of the affected territory, but also on its socio-economic consequences.

Two macro-economic indicators, secured by significant conventional thresholds, are commonly used to reveal and characterize the shortage situations, in particular in a regional group:

- **water resources per capita,** tension index ("water stress") with less than 1000 m^3 per year and shortage ("water scarcity") with less than 500 m^3 per year, while referring to the renewable natural water resources in average year.

Proposed by Mr. Falkenmark, the threshold values of this indicator are adapted with the countries where irrigation represents a large proportion of water demand and where a part only of the natural resources is exploitable in practice (what is thus well adapted to the Mediterranean).

- **the resources exploitation index,** ratio withdrawals/resources of renewable natural water (%), indicates a presumption of tension (with local or random shortages) above 50%, and structural general shortage to the approaches and above 100%.

In short:

Indicators	Situations	
	Tension (water stress)	Structural shortage
Resources per capita	1000-500 m^3/year	<500 m^3/ year
Exploitation index	50 à ~ 100%	>100%

[3] All data in this chapter are provided by Plan Bleu http://www.planbleu.org/indexUK.html

The estimates according to these two indicators are naturally strongly correlated, in particular in the Mediterranean area.

These indicators have however two defects which can make the evaluations too optimistic:

- National calculations, by whole country, level intern regional inequalities and can mask tension situations or local shortage. In the same way the reference to the average resources conceals the random shortages related to climate risks.
- the references to the natural resources thus do not take enough account of the inter-annual variations of the random shortages presumptions ascribable with the droughts.

Both indicators are well suited to strategic planning when based on demographic projections and future water demand estimated according to various scenarios.

2) Current situations of water scarcity and outlook

In the Mediterranean, the situations or the risks of water shortage are generally ascribable at high level and the growth of demand despite limited renewable water resources- and mainly irregular and unequal qualities- thus with availabilities that rarefy.

As a result of the diversified distributions of the water resources and uses as a whole of the Mediterranean area, it is by comparing the respective geographies of the ones and others, by means of the above-mentioned indicators, that one can highlight tension situations or present or future shortage, while proceeding initially, more conveniently, by country (Figures 1 and 2), in spite of the reserves indicated.

Figure 1: Renewable natural resources per capita per year in Mediterranean countries 2000-2025

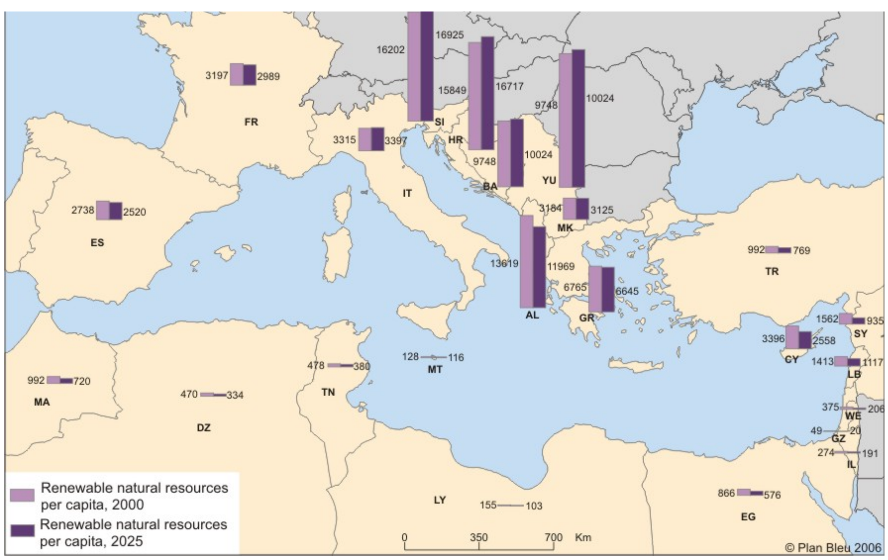
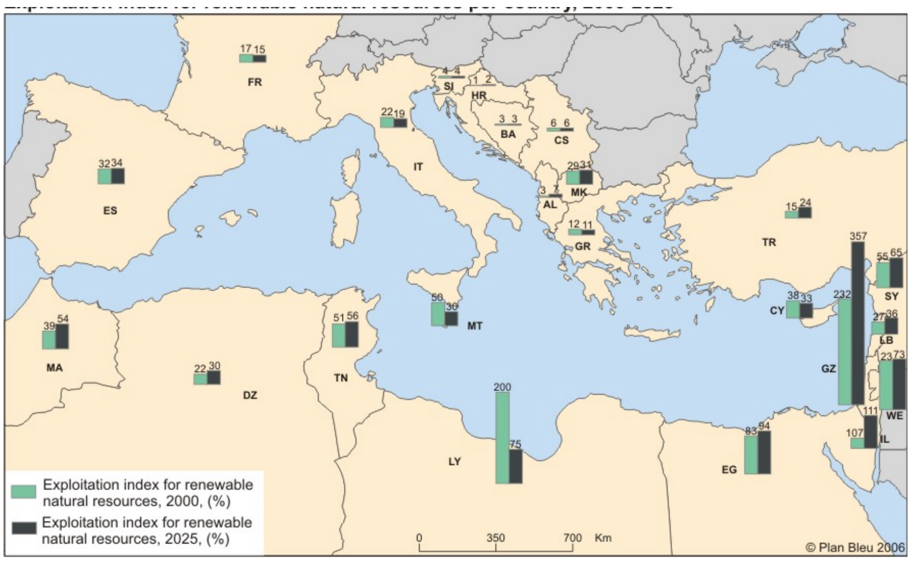


Figure 2: Exploitation index for renewable natural resources per country, 2000-2025



Figures are presented in appendix (table 17), which makes it possible to compare the situations of each Mediterranean country in 2000 and 2025 (according to population projections "variable medium" of the United Nations (2003) and following demands trend projections) on the constancy assumption of the reference renewable natural water resources.

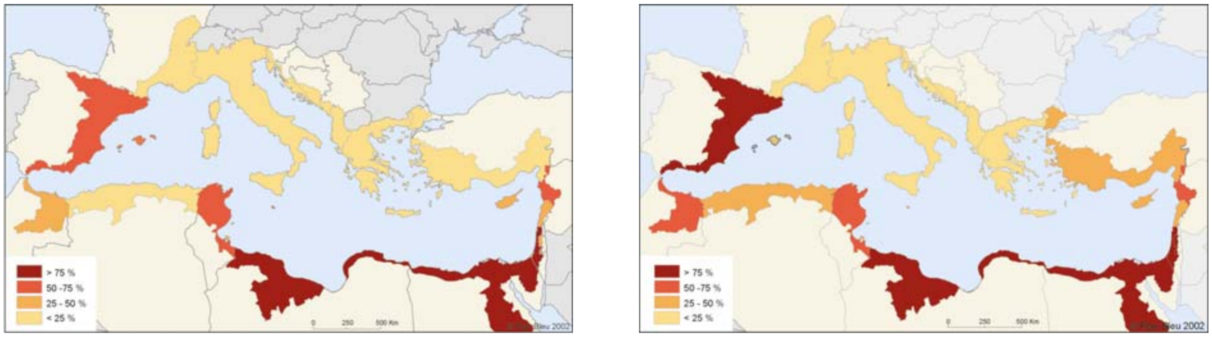
The same exploitation index of the renewable natural resources calculated for the Mediterranean catchment basin for 2000 and 2025 as shown in figure 3 highlights the variety of situations:

- A first group of countries, where water withdrawals are close to or exceed the average annual volume of renewable natural resources (exploitation index equal to or greater than 75 %), i.e. in 2000 Egypt, Israel and Libya, to be joined by 2025 by the Palestinian Territories and Spain's Mediterranean basins. The natural resources in all these countries are already very highly stressed and they will have to meet a growing part of their demand from other "unconventional" sources.

- A second group of countries where total demand represents a growing share of the average annual volume of renewable natural resources, but where the exploitation index will stay between 50 and 75 % until 2025: Malta, Syria and Tunisia.

- A third group of countries, where the exploitation index lies between 25 and 50 %, may nevertheless experience local or exceptional stress: Lebanon, Cyprus, Morocco, joined by Turkey and Algeria by 2025.

- A fourth group of countries where the exploitation index is less than 25 %: Greece and the Eastern Adriatic, France and Italy, where total demand is dropping.



2000 **2025**

☹ Pressure on water is growing in the South and East ☺ Pressure is decreasing in the north, except in Spain

Figure 3: Exploitation indices per basin, 2000-2025

The corroboration of these indicators in the Mediterranean region consolidates the analysis, owing to the predominance of agriculture in water demand. Groundwater overexploitations which explain current exploitation indices >100% in some countries are clear shortages symptoms. The high exploitation indices can be presumed to show that water demands cannot be entirely covered any more by the conventional resources exploitation and must partly use non-renewable resources or non-conventional supply sources (wastewater re-use, desalination).

Almost all the Mediterranean countries of the South and the Middle East are right now in tension situation or shortage according to these national indicators. In 2025, the tension situation will have occurred in Syria and Egypt will approach the shortage situation. A finer regionalization reveals moreover situations of more local shortage present in several countries of the South (Algeria, Morocco) or North (Mediterranean Spain, South Italy, Greece, Turkey).

It is more difficult to regionalise water resources projections per capita deduced from the population projections (2025) - and minored by potential reductions due to climate change, especially in the South - and forecast evolutions of water demands in baseline scenarios. However these projections foresee shortage extensions and aggravations in several countries, in the Maghreb and the Middle East.

In 2025, the populations in water stress situation or water shortage, according to the indicator "resources per capita", will rise to 244 million, 44% of the total population of the Mediterranean countries on this date, in average projection (without counting certain local situations in countries of the North).

Can one assess the future water shortages by considering the "deficits" estimated: surpluses of the projected demands, in baseline scenarios, on the exploitable renewable resources? Calculations of differences between demands and resources overall by country are significant only in the countries where the system of resources and uses is unified, either by nature (Egypt), or by water projects (Israel, Libya); elsewhere these national comparisons can mask local deficits (Maghreb, Syria).

In the whole of the South and the Middle East countries, the deficits could be about 50 km3/year (including 30 in Egypt, 7 in Libya, 1 in Israel) in 2025.

3) Droughts and water scarcity in the Mediterranean

As they are climate risks (rainfall deficiencies in relation to the annual or seasonal average) with hydrological consequences, that is to say consequences on renewable water resources, droughts are quite naturally the principal cause of random water shortage due to lack of water resources in all places where water demands are close in quantity to average annual water "blue water" resources; this is moreover because "green water" deficits (soil humidity) increase irrigation water demand: the drought both reduces available water resources, while increasing the demands for natural water.

The droughts typology and their impacts are summarized in the diagram below:

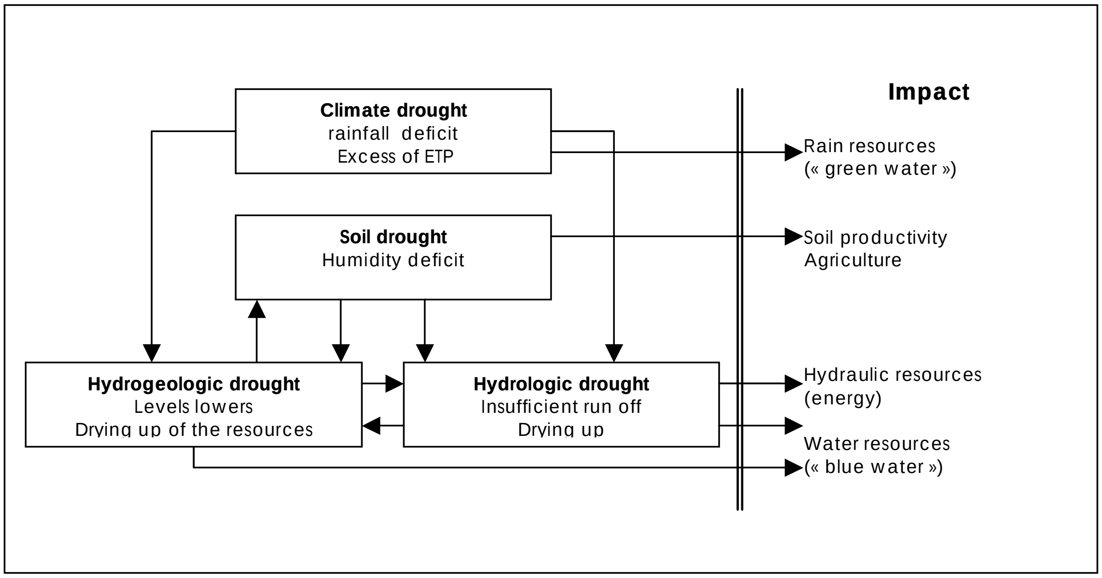


Figure 4: The droughts typology and their impacts

In the Mediterranean region, where the climate is already characterized by a normal dry season (summer), an "annual" drought can consist of:

- contribution deficit (effective rainfall) in winter and spring, with hydrological consequences principally, that is to say on resources, especially inasmuch as the regimes are irregular; therefore on the resources, more especially as the regimes are irregular;
- and/or stressing of the summer drought (fuller and longer) with immediate consequences on the soils and vegetation, and resulting in differed hydrological effects, which impact directly on water demands (in particular of additional irrigation),and indirectly on the resources as a result of their increased exploitation.

Locally, the severity of a seasonal or annual drought can be characterized in several ways (either by the extent of departure from the average of the period, measured in standard deviation; or by a frequency of conventional occurrence compared to a median), which makes it possible to draw up statistics. For example:

- Marseille, between 1840 and 1975, 73 dry years occurred, 41 with moderate drought (less than 1 standard deviation), 29 with strong drought (1 to 2 standard deviation) and 3 with very strong drought (> 2 standard deviation).
- Tunis, over 110 years, 55 droughts with insufficient rainfall (lower than the average), 32 moderate droughts and 23 strong droughts, were counted according to the same criterion (Benzarti, 1990).

- Athens, over 132 years, 12 "severe" droughts (> 1,5 standard deviation) (Baloutsos, 1993).
- Oujda (Morocco), between 1932 and 1996, 21 dry years (with rainfall lower than those of deciles 3) were counted out of 65.

The spatial extension of droughts is naturally a multiplying factor: it can affect vast areas, indeed whole countries, defraying the chronicle of the media and preoccupying the political authorities.

Droughts in several successive years are common and worsen the situations, by supporting the drying up of soil and subsoil reserves.

The evaluation of the intensity and the gravity of a drought must be based at the same time on various variables of natural state (duration, geographical extension, variation with the averages known as "normal") and on the socio-economic estimate of the consequences. Various indicators were proposed, like the Palmer index (1995), but were still not applied to the Mediterranean droughts classification.

The renewable natural water resources are unequally sensitive or "resistant" to the annual or multi annual droughts, depending on the regulating capacities either of the aquifers, or of the possible developments (dams), which are very unequally divided in the Mediterranean region.

Lessening the impact of random water shortages ascribable to droughts must therefore combine, in various measures, the storing of water by hydraulic developments, the storing of food supply, and assurance procedures.

4) Link between the EU Water Framework Directive and water scarcity and drought issues

There is a Europe-wide awareness of the full range of values water offers the population's well-being, from livelihoods to recreational, from aesthetics to culture. This recognition is clearly reflected in the Water Framework Directive, adopted on 23 October 2000[4]. WFD defines a European framework for water management and protection at each hydrological basin level. Aiming to preserve and restore good water status to both surface and groundwater sources by 2015, the WFD gives priority to environment conservation through participatory and consultative programs.

The WFD requires the establishment of a river basin management plan by 2009 and the implementation of a programme of measures in 2012.

It raises the issue of water floods and droughts in its article 1 which emphasizes the need to:

- prevent further deterioration (articles 1.a and 4)
- promote sustainable water use based on a long-term protection of available water resources (article 1.b)
- contribute to mitigating the effects of floods and droughts (article 1.e)
- contribute to the provision of the sufficient supply of good quality surface water and groundwater as needed for sustainable balanced and equitable water use

In addition, the WFD requires that "good quantitative status" of groundwater bodies (balancing abstractions with recharge) is attained, thus supporting sustainable water abstraction regimes, even in water stress and shortage situations. Furthermore, groundwater levels should not be subject to anthropogenic alterations that might have impacts on surface

[4] "Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for the Community action in the field of water policy" http://ec.europa.eu/environment/water/water-framework/index_en.html

waters. Water quantity can have a strong impact on water quality and therefore on the achievement of ecological status.
It will also be essential to encourage participatory ecosystem-based management, to provide the minimum flow of water to ecosystems for conservation and protection and to ensure sustainable use of water resources.
In conformity with WFD regulations, member states are responsible for protecting, enhancing and restoring all bodies of surface water to achieve good status. In practice, this is carried out through the implementation of monitoring programs (article 8) which cover:

- the volume and water level or rate of flow to the relevant extent for ecological and chemical status and ecological potential.
- the ecological and chemical status and ecological potential properly speaking.

For groundwater, monitoring programs relate to chemical and quantitative status.
With regards to groundwater, a Groundwater Daughter Directive defines the requirement under article 17.1 to "prevent and control groundwater pollution". While it is important in this regard to derive criteria to assess groundwater status and identify significant upward trends, this should not preclude the early adoption of simple pragmatic measures to protect groundwater quality. This is even more valid considering that a groundwater protection regime against pollution is already mandatory under the directive 80/68/EEC[5].
By adopting the WFD, the EU has thoroughly restructured its water protection policy. The directive requires that integrated management plans be developed for each river basin in order to achieve good ecological and chemical status. Although the WFD will contribute to the mitigation of the effects of droughts, it is not one of its principal objectives. In most cases, droughts are identified too late and emergency measures are undertaken in a hasty way. The latter are not, in general, sufficiently effective. Clear and consistent criteria for an early detection and warning of drought situations need therefore to be established. Such criteria would allow sufficient time, before and at the beginning of a drought event, to look for suitable responses in the management of a water resource system.
The WFD additionally considers that prolonged droughts "cannot reasonably have been foreseen" (article 4.6). Prolonged droughts are therefore "grounds for exemptions from the requirement to prevent further deterioration or to achieve good status" (Preamble (32)) where "additional measures are not practicable" (article 11.5). The measures that directly relate to drought mitigation are left as optional supplementary measures (WFD Annex VI, Part 5).

[5] See http://ec.europa.eu/environment/water/water-framework/groundwater.html

1. CHAPTER I: DEFINITIONS AND ASSESSMENT OF THE DIFFERENT PHENOMENA

1.1. Preamble

Water scarcity issues are becoming emergency issues and are going to play a key role in the near future for the definition of both environmental and development policies on a global scale.

Regarding Europe, the 2003 and 2005 drought events especially in Spain and France definitely confirm this trend and the urgent need for the implementation of common strategies to face the problem, which involve the whole European Community and not only Mediterranean countries.

The 2005 drought in Spain, Portugal, and parts of France was caused by a low precipitation rate on all the territory in 2004; in Spain the annual average precipitation has been lower than the minimum measured in the historical series from 1947 to 2003. This extreme reduction of rainfall (from 650 mm to 400 mm) resulted in significant impacts on water stored in reservoirs, drinking water availability, hydropower potential, water quality, environmental stress, and fire risk. This situation called for the execution of special plans for situations of alert and eventual drought, implementing respective management measures such as irrigation restrictions, and setting emergency measures.

With respect to France, from September 2004 to September 2005, the drought involved a large part of the national territory and was still real at the beginning of October 2005 in the Poitou-Charente and Loire departments. The annual precipitation of 2005 was lower than the last fifty years' average. Every year since 1997, at least twenty departments adopted water use restrictions. The Drought Action Plan adopted in 2004 after the 2003 drought crisis has been reactivated and updated in 2005 to face this new event. At the end of October 2005, mid-term action was still necessary to balance water supply and demand, and water scarcity has become a priority for strategies of the French Government.

However, droughts cannot be considered as local phenomena; according to recent studies drought episodes have occurred more frequently during the last decades on a global scale. The percentage of Earth's land area stricken by serious drought more than doubled from the 1970's to the early 2000's. Based on this information, it is often reported by climate change watch organizations such as the Intergovernmental Panel on Climate Change (IPCC, 2002), that drought severity and frequency have increased in some of the Earth's regions in conjunction with climate change, although clear evidence for this is not yet conclusive.

1.2. Definition and Assessment of Drought

1.2.1. Drought definitions

Drought is a normal, recurrent feature of climate, although often erroneously considered an unexpected and extraordinary event. It occurs in virtually all climatic zones, but its characteristics vary significantly from one region to another. Drought is a temporary aberration within the natural variability and can be considered an insidious hazard of nature; it differs from aridity which is a long-term, average feature of climate.

Droughts generally result from a combination of natural factors that can be enhanced by anthropogenic influences. The primary cause of any drought is a deficiency in rainfall, and, in particular, the timing, distribution, and intensity of this deficiency in relation to the

existing water storage, demand, and use. This deficiency can result in a shortage of water necessary for the functioning of a natural (eco-) system, and / or necessary for a certain human activities.
High air temperatures and evapotranspiration rates may act in combination with lacking rainfall to aggravate the severity and duration of a drought event. High air temperatures in summer, when associated with clear skies and sunshine, increase evapotranspiration to the extent that little or no rainfall is available for groundwater or river recharge. Winter droughts are caused by precipitation being stored in the catchment in the form of snow and ice, preventing any recharge of rivers or aquifers until air temperatures rise again and snow melting starts. Both precipitation and air temperature are, in turn, driven by the atmospheric circulation patterns. Consequently, any change in the position, duration, or intensity of high-pressure centres (anticyclones) would lead to changes in the prevailing circulation pattern, thus producing precipitation and air temperature anomalies. Drought is also related to the timing (i.e. principal season of occurrence, delays in the start of the rainy season, occurrence of rains in relation to principal crop growth stages) and the effectiveness (i.e. rainfall intensity, number of rainfall events) of the precipitation. Other climatic factors such as high wind velocities and low relative air humidity are often associated with a drought event in many regions of the world, and can significantly aggravate its severity.
It is important to differentiate between aridity, which is restricted to low rainfall regions as a long-term average feature, and a drought situation that indicates a deviation from the average situation, but still within the ecosystem's natural variability. It is very important to discern among transitory periods of water deficiency, a cause of exceptional droughts, and long-term imbalances of available water resources and demands, as reflected in figure 5.

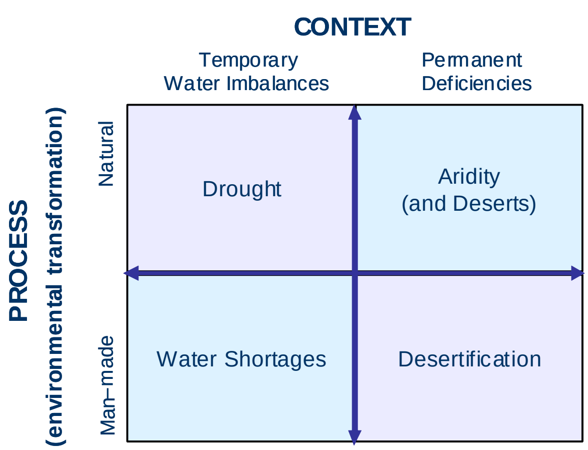


Figure 5: Typology of water stress condition (Vlachos, 1982).

Operational Definitions of Drought

Operational definitions allow for the identification of onset and end as well as of the degree of severity of a drought. These definitions are categorized in terms of four basic approaches to identify and describe drought events: meteorological, hydrological, agricultural, and socio-economic droughts. The first three approaches consider a drought as a natural, physical phenomenon. The latter one regards a drought event in relation to anthropogenic supply and demand, thus tracking the effects of water shortfall as it passes through the socio-economic system.

Meteorological drought

Meteorological drought is usually an expression of precipitation's negative departure from normal over some periods of time. The exact definition is usually region-specific, and often based on a thorough understanding of regional climatology. The variety of meteorological definitions in different countries illustrates why it is not possible to apply a definition of drought developed in one part of the world to another without any modifications.

Agricultural drought

Agricultural drought occurs when there is not enough soil moisture to meet the needs of a particular crop at a particular time. Typically, agricultural drought happens after meteorological drought but before hydrological drought. Non-irrigated agriculture is usually the first economic sector to be affected by drought.

An operational definition for agricultural drought might compare daily precipitation values to evapotranspiration rates to determine the rate of soil moisture depletion, model soil moisture by a soil water balance model, or measure soil moisture directly, and then express these relationships in terms of drought effects on plant behaviour (i.e. growth and yield) at various stages of crop development. Such a definition could be used in an operational assessment of drought impact and severity by tracking meteorological variables, soil moisture, and crop conditions during the growing season, continually re-evaluating the potential impact of these conditions on final yield.

Hydrological drought

Hydrological drought refers to deficiencies in surface and subsurface water supplies. It is determined from measurements of stream-flows and lake, reservoir, and groundwater levels. There is a time lag between the lack of precipitation and decreased water levels in streams, rivers, lakes, and reservoirs; accordingly hydrological measurements are not the first indicators of a drought event. However, they reflect the consequences of reduced precipitation over an extended period of time, taking into account the effects of soil and vegetation. As another consequence, the end of a hydrological drought might be lagging behind the end of the corresponding meteorological drought, as considerable quantities of precipitation are required to restore river and lake levels back to their normal conditions.

Although climate is a primary contributor to hydrological drought, other factors such as changes in land use (e.g. deforestation), land degradation, or the construction of dams affect the hydrological characteristics of the basin. As regions are interconnected by hydrologic systems, the impact of meteorological drought may extend well beyond the borders of the precipitation-deficient area and cause a hydrological drought where the local precipitation rate shows no large deficit.

Similarly, changes in land use upstream may alter hydrologic characteristics such as infiltration and runoff rates, resulting in more variable streamflow and a higher incidence of hydrologic drought downstream. Land use change is one of the ways human interventions alter the frequency of water shortage even when no change in the frequency of meteorological drought has been observed.

Socio-economic drought

Socio-economic drought definitions associate the supply and demand of some economic good with elements of meteorological, hydrological, and agricultural drought. It differs from the aforementioned types of drought because its occurrence depends on the time and space processes of supply and demand. Supply of many economic goods such as drinking, process, or cooling water, forage, food grains, fish, or hydroelectric power, depends on the climatic conditions. Because of the natural variability of climate, water supply can be ample in some years, but unable to meet human and environmental needs in other years. Socio-economic drought occurs when the demand for an economic good exceeds supply as a result of a weather-related shortfall in water supply.

To determine the onset of a drought event, operational definitions usually specify the degree of departure from average of the climatic variable under consideration over some time

period. This is done by comparing the current situation to the historical average, often based on a 30-year period of record. The threshold identified as the beginning of a drought (e.g. 75 % of average precipitation over a specified time period) is usually established somewhat arbitrarily, rather than on the basis of its precise relationship to specific impacts.
Operational definitions can also be used to analyze drought frequency, severity, and duration for a given historical period. Such definitions, however, require detailed meteorological and corresponding impact data (e.g. crop yield), depending on the nature of the definition applied. Developing a climatology of drought for a region provides a greater understanding of its characteristics and the probability of recurrence at various levels of severity. Information of this type is extremely beneficial in the development of response and mitigation strategies and preparedness plans.

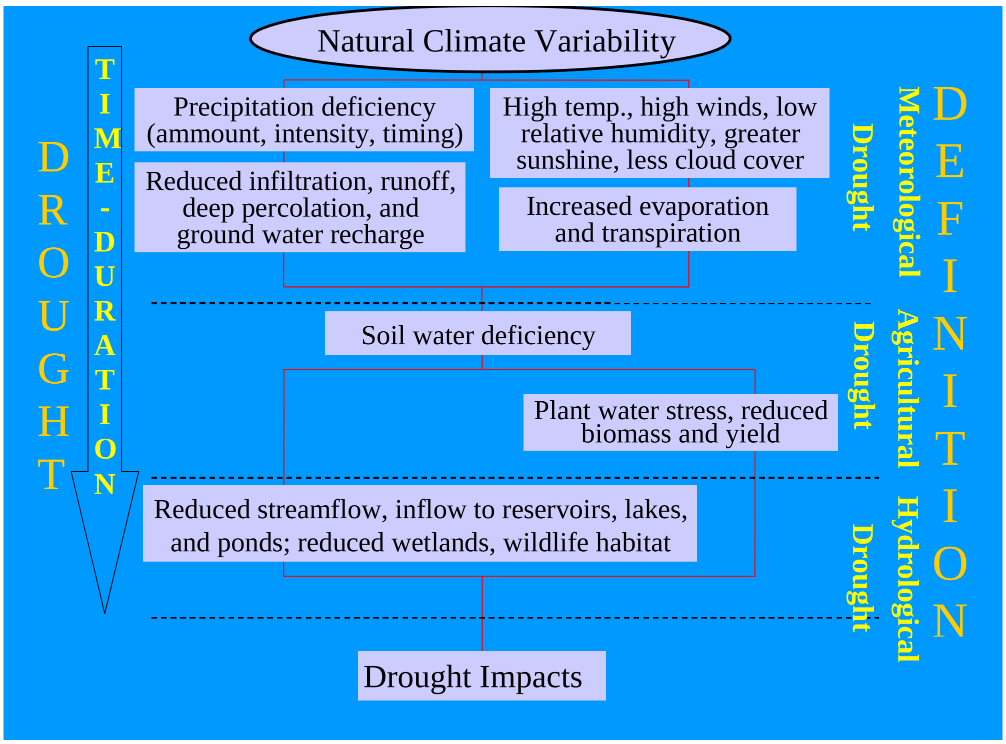


Figure 6: Sequence of drought due natural climate variability (National Drought Mitigation Centre, USA, Drought Watch)

Drought Management Definitions

Drought management definitions help water resources managers and researchers to understand, clarify, and develop technical terms and concepts. Various definitions exist within the wide field of risk management, in which the natural hazards and disaster management community has a somewhat different approach than the perception of risk within the climate change community (e.g. Brooks 2003). Therefore it is important to agree upon a common terminology before using general expressions such as hazard, risk, or mitigation. The following terminology has been used within the MEDROPLAN[6] project and can serve as a basis for drought risk management from the natural hazards point of view.

Hazard

[6] See Chapter 2

Hazard is the probability of occurrence of a potentially damaging event, phenomenon or activity, which may cause the loss of life, property damage, social and economic disruption or environmental degradation. In case of drought, it refers to the probability of a reduction in water supply that makes the supply of water inadequate to meet the demand.

Drought Impact

Drought impact is the specific effect of drought on the economy, on the social life and on the environment, which are symptoms of vulnerability.

Vulnerability

Vulnerability is the magnitude of losses resulting from a potentially damaging phenomenon. It comprises exposure – the values and lives present at the respective location – and their lacking capability of resistance or defence to the threat. Vulnerability is an aggregate measure of human welfare that includes environmental, social and economic exposure to a range of harmful perturbations.

Risk

Risk is the result of imposing a hazard on something or someone that is vulnerable to that hazard. Risk may be quantified as the expected losses due to a particular hazard for a given area and reference period (i.e. hazard x vulnerability = risk).

Risk analysis and assessment

The process of identifying and understanding the relevant components associated with drought risk, as well the evaluation of alternative strategies to manage the associated risk resulting from the drought (i.e. risk management).

Capacity to face 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 through activities and measures taken in advance to ensure effective response to a potential impact of damaging events.

Prevention

Prevention is the reduction of risk through the activities that provide outright avoidance of the adverse impacts of potentially damaging events.

Mitigation

Mitigation is the set of structural and non-structural measures undertaken to limit the adverse impact of potentially damaging events (i.e. adaptation).

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.

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. It is an important element of preparedness.

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.

1.2.2. Drought causes

Drought due to natural factors

When precipitation over a given region performs poorly and is accompanied by relatively high evaporation rates for prolonged periods, a drought occurs. Drought differs from other natural disasters in its slowness of onset and its commonly lengthy duration. In most cases, drought is caused by either a deficiency of precipitation or an inadequacy of inland water resources supplies for a prolonged period. “Inadequacy” in this context is a relative word, and is determined by the specific requirements in the sector or activity.

Before the rise of modern water-consuming cities, drought was predominantly an agricultural disaster. Now, with large urban agglomerations - especially in semi-arid regions - having expanded faster than water supplies can be made available, the spectre of drought faces both the farmer and the urban dweller. Since most inland water resources are usually sustained by precipitation, inadequate precipitation is usually the major cause of drought. This inadequacy is usually caused by an unfavourable performance of the factors which drive the climate system over the affected region. Precipitation anomalies are a naturally recurring feature of the global climate. These anomalies affect various components of the hydrologic cycle to produce a drought. Climatologies of precipitation, temperature, and atmospheric moisture provide an indication of the frequency and intensity of precipitation, the correlation of precipitation and temperature, and the atmospheric drying that occurs during droughts.

Shifts in atmospheric circulation, which cause drought, may extend for time scales of a month, a season, several years or even a century. The latter might be termed a climatic shift, but the effect on humans and their environment is equally great. Because of the economic and environmental importance of drought, determined efforts are being made to solve the problem of prediction of the atmospheric circulation patterns that produce droughts. Empirical studies conducted over the past century have shown that meteorological drought is never the result of a single cause but the result of many causes, often synergistic in nature.

Anthropogenic factors enhancing drought impacts

The causes of water scarcity are manifold, and human activities contribute to the development of drought conditions. The current debate regards the causes as largely deterministic in that scarcity is a result of identifiable cause and effect. However, if water scarcity is the point at which water stress occurs then there are also less definable sociological and political causes. Many of the causes are inter-related and are not easy to distinguish. Some of the main causes are listed below. The list is not in order of priority although some causes have greater impact than others.

Population growth

The main cause of growing water scarcity is the growing demand resulting from population increase. The world's population is growing rapidly: in 2020 it is projected to be 7.9 billion, 50 % larger than in 1990 (Dyson, 1996). Most of this growth will be in countries whose inhabitants have low levels of household water consumption, and in which the use of water-intensive appliances is likely to grow. Many of these countries are also rapidly urbanising, and the task of obtaining sufficient water and distributing it to the newly urbanised households will be a major financial and environmental challenge to many authorities. The major increase in demand is due to the development needs of the growing population and, primarily, from the need to grow sufficient food to feed the increasing population.

Climatic change and variability

There is a great deal of debate regarding the issue of global climate change. Whilst there is a wide-spread view that global warming is happening, this is yet to be conclusively scientifically proven and the effect of this phenomenon on water resources is unknown. The consensus is that the effect will be to accentuate the extremes with more pronounced droughts and more severe flooding (Climate Change 2001: Impacts, Adaptation and Vulnerability - IPCC, 2001). If it persists, climatic zones are likely to migrate, leaving the climate of some regions dryer, others wetter, and all more variable and unpredictable (Schaer et al. 2004). Certain regions dependent on water (e.g. major farming areas, or large population centres) will experience more water scarcity, while others will become more humid. It is an open question what the net effect on water supply will be, but in any case there will be transitional and frictional costs in regions that become drier.

Land use

The degradation and land use conversion of watersheds and catchments may reduce the amount of usable water available downstream. While reduction of vegetation cover may result in higher runoff, it reduces groundwater infiltration and the storage capacity of dams and lakes through sedimentation. The draining of large scale wetlands or large scale deforestation may change the micro-climate of a region.

The consequences of poor land management and farming methods risk pushing communities ever closer to the point of vulnerability where even small changes in conditions can have disastrous effects.

Another issue related to land use is the development of "thirsty" crops, particularly in sensitive areas such as mountain catchments, surroundings of wetlands or already water stress facing regions.

With regards to Europe, it has been estimated that about 42 % of the total land area is farmland (comprising 24 % arable, 16 % permanent crops, and 2 % grassland), 33 % forest and 1 % urban (EEA, 1995). The European Union, as part of its reform of the Common Agricultural Policy, is committed to a policy of increasing afforestation. In Europe as a whole, forest cover has increased by about 10 % over the past 30 years and it is calculated that each decade 2 % of agricultural land is lost to urbanisation. Both these changes will have a significant effect on the hydrology of the local area. It is generally accepted that afforestation of a catchment reduces mean run-off, through increased interception and evapotraspiration, but is important to stress that this effect must be balanced with the important ecological functions played by a forested catchment in terms of protection from soil erosion and nature conservation. The precise impact on the streamflow will, however, vary depending on the type of forest, density of planting and land management practice.

Urbanisation has been shown to lead to increased surface run-off, reduced infiltration and reduced baseflows locally. In Mediterranean regions, the semi-arid climate coupled with poor land and crop management can lead to land degradation. It is estimated that about 44

% of Spain is affected by some kind of soil erosion. Soil erosion reduces the capacity of infiltration and increases the vulnerability of a region to drought.

Water quality

The pollution of water supplies reduces the availability of clean water for usage. This is particularly severe during times of water shortages. In normal conditions the capacity of a river to accept a given pollution load is determined by the average dilution factor. As water becomes scarcer, rivers and streams become increasingly sensitive to the effects of pollution, as do those human and other living organisms which depend on the water. This may happen to surface supplies (e.g. a river or lake used for drinking water supply) or groundwater, and the pollution may origin from industrial discharge, agro-chemical runoff from agricultural fields, the illegal disposal of civil discharges, or the release of insufficiently treated sewage from municipal works. Seen from the other point of view, the reduction of water pollution can increase the usable water supply.

Water demand

A growing and unmanaged demand for water will accelerate the arrival of conditions of scarcity. The widespread misconception that there is plenty of water and that the only problem is getting it to the right place at the right time still persists as a relict of the supply driven water resources management. Reducing and managing the demand for water, enforcing the efficiency of use and introducing water conservation measures requires policy and legislative attention.

Legislation and water resource management

Poor or inadequate legislation can exacerbate the effects of water scarcity. Legislation acts which give exclusive rights to some users are necessary to provide security for investment (usually in the agricultural sector), but they can result in serious jeopardy during times of scarcity. Water resources management and development policies can also have a direct effect on the capacity of some sectors to survive water scarcity periods. If these are inequitable, inefficient, or do not provide for at least the basic needs of all citizens, then a particular occurrence of water scarcity will result in conditions of drought.

International waters

The use of water in international rivers of cross-boundary catchment areas by upstream countries may lead to conditions of drought in downstream countries. This is a problem which is obviously exacerbated during times of scarcity. It is important that communication is maintained between riparian countries through a variety of mechanisms including special protocols, joint commissions, memoranda of agreement, treaties etc. It is important that these agreements are established during times of water abundance rather than in times of crisis.

Political realities

Politicians and decision-makers are the persons who have greatest influence on the allocation of scarce financial budgets and the adoption of policies. Unfortunately, the temporal perspective of many politicians does not coincide with the temporal dimension of a prudent water resources management, resulting in decisions being made on the basis of short term political benefits only.

Drought perceptions in different climatic zones

The observed changes in precipitation rates over Europe in the 20th century follow the general hemispheric trend of increasing precipitation at mid and high latitudes and decreasing precipitation in the subtropics (Climate Change: the scientific basis – IPCC, 2001). The observations show a strong decadal variation in drought frequency.

Northern Europe

Annual precipitation over Northern Europe has increased by between 10 % and 40 % in the last century; the strongest increases are found in Scandinavia and Western Russia. The changes in Central Europe are less pronounced and include both increases (in the western part) and decreases (in the eastern part). The trend towards increasing precipitation in Northern Europe would continue at a rate of 1 % to 2 % per decade. An increasing trend is expected for the winter as well as the summer season. The projected changes for Western and Central Europe (e.g. France and Germany) are small or ambiguous.

Southern Europe

Most of the Mediterranean basin has experienced up to 20 % reduction of precipitation during the last century. The projections for the 21st century show further decreases in precipitation over Southern Europe, but not by more than, at most, about 1 %. Contrary to Northern Europe, there is a marked difference between the seasons: apart from the Balkans and Turkey, Southern Europe can expect more precipitation in the winter while in the summer precipitation is projected to decrease by up to 5 % per decade. The effects of aerosol pollution over the Mediterranean, implying sea-surface cooling and heating of the atmosphere, are likely to contribute to the reduced summer precipitation in the region (Climate Change: the scientific basis – IPCC, 2001).

1.2.3. Drought indices and indicators

Because there is no single definition for drought, its onset and termination are difficult to determine. In fact, as a drought does not begin with an extreme meteorological event, like a flood, its onset may be difficult to recognize for stakeholders. Rather, the onset of drought is gradual and drought usually hits different regions of a country, with varying levels of intensity and at different moments. A drought indicator is an objective measure of the system status that can help agencies identify the onset, increasing or decreasing severity, and end of a drought. But no single indicator or index alone can precisely describe the onset and severity of the event. As a consequence of these characteristics, effective early-warning systems for drought must be base based on multiple indicators to fully describe a drought event development and severity (see chapter 1.3).

Tracking various indicators provides crucial means to monitor drought. Common indicators of drought include meteorological variables such as precipitation and evaporation, as well as hydrological variables such as stream flow, groundwater levels, reservoirs and lakes levels, snow pack and soil moisture. Numerous climate and water supply indices are in widespread use to picture the severity of drought conditions and to represent it in a probabilistic perspective. Each index has strengths and weaknesses which need to be clearly understood before being applied.

Drought indices assimilate a large number of data into a comprehensible big picture. A drought index value is typically a single number, far more useful than raw data for decision making. There are several indices that measure how much precipitation for a given period of time has deviated from historically established norms. Although none of the major indices is inherently superior to the rest in all circumstances, some indices are better suited than others for certain uses. In the international publications different indices have been discussed and applied. Among those we mention:

- Percent of Normal
- Deciles

- Palmer Drought Severity Index (PDSI)
- Surface Water Supply Index (SWSI)
- Standardized Precipitation Index (SPI)

The interest in developing indexes is represented in the scientific literature by new approaches such as PAI – Palfai Aridity Index (Palfai, 2002), or RDI - Reconnaissance Drought Index (Tsakiris, 2004), among others. Furthermore, plans generally call for certain measures to be initiated when a drought indicator reaches a predefined level. Trigger levels can be refined through computer modelling to strike an acceptable balance between the frequency of drought declarations and the effectiveness of an early response. The nature of the indicator and the level at which responses are triggered should be selected to reduce economic and environmental consequences.

1.2.4. Drought impacts per sector

Drought should not be viewed as a merely physical phenomenon or natural event. Its impacts on society result from the interplay between a natural event (less precipitation than expected resulting from natural climatic variability) and the demand people place on water supply.

When a drought event begins, the agricultural sector is usually the first to be affected because of its heavy dependence on stored soil water. Soil water can be rapidly depleted during extended dry periods. If precipitation deficiencies continue, sectors dependent on other sources of water will begin to feel the effects of the shortage, too.

Sectors relying on surface water (i.e. reservoirs and lakes) and subsurface water (i.e. groundwater) are usually the last to be affected. A short-term drought that persists for 3 to 6 months may have little impact on these sectors, depending on the characteristics of the hydrologic system and water use requirements.

When precipitation returns to normal and meteorological drought conditions have abated, the sequence is repeated for the recovery of surface and subsurface water supplies. Soil water reserves are replenished first, followed by stream-flow, reservoirs, lakes, and groundwater. Drought impacts may diminish rapidly in the agricultural sector because of its reliance on soil water, but linger for months or even years in other sectors depending on stored surface or subsurface supplies. Groundwater users, often the last to be affected by drought during its onset, may be last to experience a return to normal water levels. The length of the recovery period is a function of the intensity of the drought, its duration, and the quantity of precipitation received as the episode terminates.

Drought produces a complex matrix of impacts that spans many sectors of the economy and reaches well beyond the area that is physically experiencing the drought.

Impacts are commonly differentiated into direct and indirect. Reduced crop, rangeland, and forest productivity, increased fire hazard, reduced water levels, increased livestock and wildlife mortality rates, or damage to wildlife and fish habitat are examples of direct impacts.

The consequences of the direct impacts lead to indirect impacts. For example, a reduction in crop, rangeland and forest productivity may result in reduced income for farmers and agro-industry, increased prices for food and timber, unemployment, reduced tax volume because of reduced expenditures, foreclosures on bank loans to farmers and businesses, migration, and disaster relief programs.

The impacts of drought can be categorized as economic, environmental and social (Figure 7).

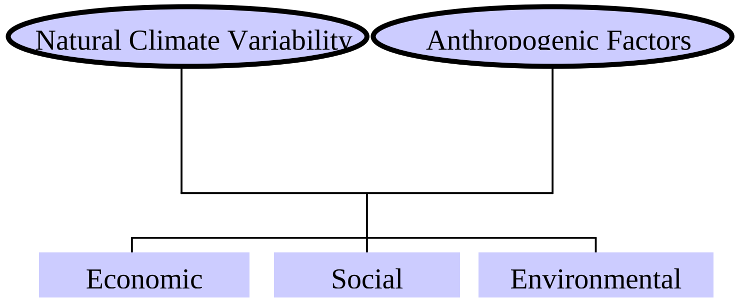


Figure 7: Sequence of drought impacts

Economic impacts

Many economic impacts occur in agriculture and related sectors, including forestry and fisheries, because of the reliance of these sectors on surface and subsurface water supplies. In addition to obvious losses in yields in crop and livestock production, drought is associated to increases of insect infestations, plant diseases and wind erosion. The incidence of forest and range fires substantially augments during extended droughts, which in turn places both human and wildlife populations at higher levels of risk.

Income loss is another indicator used in assessing the impacts of drought because a lot of sectors are affected. Reduced income for farmers has a ripple effect. Retailers and others who provide goods and services to farmers face reduced business, leading to unemployment, increased credit risk for financial institutions, capital shortfalls and loss of tax revenue for government. Less discretionary income affects recreation and tourism industries. Prices of food, energy and other products increase as supplies are reduced. In some cases, local shortages of certain goods result in the need to import these goods from outside the stricken affected region. Reduced river discharge impairs the navigation on rivers and causes an increase of transportation costs, because products must be transported by rail or road. Hydropower production may also be curtailed significantly. For the 2003 summer drought in Europe, the MunichRe reinsurance company estimated economic losses of approximately US$ 13 billion, of which large parts were not insured (MunichRe 2004).

Environmental impacts

Environmental losses are the result of damages to plant and animal species, wildlife habitat, air and water quality, forest and range fires, degradation of landscape quality, loss of biodiversity and soil erosion. Some of the effects are short-term and conditions quickly return to normal situation after the end of the drought. Other environmental effects linger for some time or may even become permanent. These effects are enhanced, if the management of water resources is permanently not sustainable at all, as often true for wetlands (Zacharias et al., 2003). Wildlife habitat, for example, may be degraded through the loss of wetlands, lakes and vegetation. This habitat change can have negative impacts on species and, even more, their individuals. However, some species may recover from this temporary aberration. The degradation of landscape quality, including increased soil erosion, may lead to a more permanent loss of biological diversity and productivity of the landscape. Although environmental losses are difficult to quantify, growing public awareness and concern for environmental quality has forced public officials to focus greater attention and resources on these effects.

Often drought stress on plants and ecosystems is enhanced by a combination of stress factors; e.g. Matyssek et al. (2006) reviewed the interactions between drought and ozone stress in forest trees, finding a strongly reduced tolerance under exposure of the combined stress as well as a consequent reduced carbon fixation of forests. As for the 2003 summer drought in Europe, Ciais et al. (2005) found a reduction of up to 30 % in gross primary

productivity over Europe, resulting in a strong anomalous net source of carbon dioxide to the atmosphere and hence a reversion of the carbon sequestration by European ecosystems of the previous years.
Environmental impacts from irrigation can be of different types: aquifer exhaustion from over abstraction, salinization of groundwater, increased erosion of cultivated soils on slopes and water pollution by nutrients and pesticides. These impacts are not well documented in many EU member states but different case studies show that over-abstraction and salinization of aquifers occur in many parts of the Mediterranean coastline (Portugal, Spain, Italy and Greece) and some localized areas in northern Europe (the Netherlands) (Digital Atlas of Global Water Quality, UN GEMS/Water Programme). Soil erosion is particularly severe in Spain, Portugal and Greece. The desiccation of former wetlands and the destruction of former high nature value habitats are significant in different regions of both southern and northern Europe (west France, inland Spain, Hungary and southeast England).

Social impacts

Social impacts mainly involve public safety, health, conflicts between water users, reduced quality of life, and inequities in the distribution of impacts. Many of the impacts specified as economic and environmental have social components as well (see 1.3.2).

1.3. Definition and assessment of Supply/Demand Imbalances

An imbalance in water supply and demand is a situation where there is insufficient water to satisfy long-term average requirements. It is important, however, to underline the difference between imbalances, arising when water demand by society exceeds the supply capacity of the natural system, and aridity, which is a natural phenomenon, describing generally low water availability of an ecosystem due to low precipitation and/or high evaporation rates.

1.3.1. Definition of imbalances in water supply and demand

Water shortage

A water shortage can be described as any situation in which water supply is inadequate to meet demand. The term “water shortage” has the following specific meanings:

- a dearth, or absolute shortage,
- low levels of water supply relative to minimum levels necessary for basic needs.

It can be measured by annual renewable flows (in cubic meters) per head of population, or its reciprocal, i.e. the number of people dependent on each unit of water (e.g. millions of people per cubic kilometre).
The frequency and/or cause of a shortage may indicate the best way to overcome it. Droughts are temporary, but reoccurring. Thus, depending upon drought frequency, a solution to the problems created by drought may be reducing demand and/or augmenting supply. On the other hand, water contamination can put a water supply out of commission permanently, or at least until treatment technology becomes affordable. The latter case is similar to developing a new source of supply. Water shortage caused by inadequate planning or equipment may be overcome by putting attention to design and capital improvements. Shortages resulting solely from increased demand for water resources may be best eliminated through long-term resources management.
A comparison of projected supply and demand indicates whether a utility faces a potential water shortage. Ideally, a utility should know not only whether it is likely to have a shortage, but how much of a shortage. This would enable the development of responses based on the projected magnitude of an impending shortage. In reality, it is very difficult to estimate the projected magnitude of a shortage because of the difficulty involved in

estimating available supplies. Therefore, the primary objective is to determine whether a utility faces the possibility of a shortage. The secondary objective is to determine, if possible, the magnitude of this potential shortage.
Selected demand reduction options should be related to the degree of water shortage that exists. For example, imposing water rationing upon customers would be inadequate, if only a five percent deficit in your normal water supply occurred.

Water scarcity

In popular usage, "scarcity" is a situation where there is insufficient water to satisfy normal requirements. However, this common-sense definition is of little use to policy makers and planners. There are degrees of scarcity - absolute, life-threatening, seasonal, temporary, cyclical, etc. Populations with normally high levels of consumption may experience temporary scarcity more severely than other societies who are accustomed to use much less water. Scarcity often arises because of socio-economic trends having little to do with basic needs. Defining scarcity for policy-making purposes is very difficult.
The term "water scarcity" has the following specific meanings:
- an imbalance of supply and demand under prevailing institutional arrangements and/or prices,
- an excess of demand over available supply,
- a high rate of utilization compared to available supply, especially if the remaining supply potentials are difficult or costly to tap.
Because this is a relative concept, it is difficult to capture in single indices. However, current utilization as a percentage of total available resources can illustrate the scale of the problem and the latitude for policymakers.
Some causes of water scarcity are natural, others are of anthropogenic. The impact of natural processes can be aggravated by human responses. Human behaviour can modify our physical environment in a way that the availability of usable water resources is reduced. The demand for water may be artificially stimulated, so that at a constant rate of supply the resource becomes "scarce".

Water stress

Water stress is generally related to an over-proportionate abstraction of water in relation to the resources available in a particular area. The ratio between total freshwater abstraction and total resources indicates in a general way the availability of water and the pressure on water resources.
Water stress occurs when the demand for water exceeds the available amount during a certain period or when poor quality restricts its use. It frequently occurs in areas with low rainfall and high population density or in areas where agricultural or industrial activities are intense. Even where sufficient long-term freshwater resources exist, seasonal or annual variations in the availability of freshwater may at times cause stress. Water stress induces deterioration of fresh water resources in terms of quantity (aquifer over-exploitation, dry rivers, etc) and quality (eutrophication, organic matter pollution, saline intrusion, etc). Such deterioration can result in health problems and have a negative influence on ecosystems.
The Water Exploitation Index (WEI) in a country is the mean annual total demand for freshwater divided by the long-term average freshwater resources (see Introduction).

Water demand management

Water demand management refers to the implementation of policies or measures which serve to control or influence the amount of water used (EEA Glossary).
The relationship between water abstraction and water availability has turned into a major stress factor in the exploitation of water resources in Europe. Therefore, it is logical that the investigation of sustainable water use is increasingly concentrating on the possibilities of

influencing water demand in a favourable way for the water environment. Demand management includes initiatives having the objective of reducing the amount of water used (e.g. the introduction of economic instruments and metering), usually accompanied by information and educational programmes to encourage more rational use. According to the EEA, management can be considered as a part of water conservation policy, which is a more general concept, describing initiatives with the aim of protecting the aquatic environment and making a wiser use of water resources.

Water conservation

While there is no universally accepted definition of water conservation, this term is often used in the sense of "saving water" through efficient or wise use. People do not always agree on the meaning of "efficiency" because there are various degrees of efficiency. For example, efficient residential water use can range from reducing toilet tank flows and turning the tap off when water is not in use (activities that do not require significant, if any, lifestyle changes), to planting low-water-use landscapes and car washing restrictions (activities that do require environmental or lifestyle changes).

In terms of utility management activities for dealing with water shortages, conservation can mean both short-term curtailment of demand and long-term resource management. Short-term curtailment of demand can be achieved through a vigorous public information programme, which can include both voluntary and enforced actions. The curtailment is temporary, and after a shortage is over consumers usually resume their former water use habits. Long-term resource management involves efficient use and resource protection strategies designed to achieve permanent changes in how water is managed and used, including policy changes like the removal of subsidies for thirsty crops in water-scarce areas. Water supply companies and authorities often undertake activities under normal circumstances to promote efficient use of water.

Today, water conservation has many meanings. It means storing, saving, reducing or recycling water. In detail it denotes:

for farmers who irrigate

- improving application practices via surge valves, special nozzles on sprinkler systems, soil moisture and crop water needs sensors
- increasing uniformity of application, thereby allowing less water to be used
- using meteorological data to balance water applications with available soil moisture and crop water needs
- lining diversion canals and ditches to minimize seepage and leaks
- irrigating with recycled water rather than freshwater that could be used after treatment for potable water

for municipalities

- encouraging residents to install and use high efficiency plumbing fixtures and educate them about water-saving habits
- reducing peak demands to avoid the extra-costs of investing in additional pumping and treatment plants
- metering water (customers pay for what they use)
- substituting recycled water for non potable application for urban irrigation of sports facilities and parks
- increasing water storage through aquifer recharge and recovery so that excess water in the winter can be stored for summer use.

for industry

- identifying other resource-conserving methods for the production processes
- reusing treated municipal wastewater instead of potable water for process and cooling
- reusing water used in manufacturing and cooling

1.3.2. Background of water supply

The concept of water resources is multidimensional. It is not only limited to its physical measure (hydrological and hydrogeological), the “flows and stocks”, but encompasses other more qualitative, environmental and socio-economic dimensions.

The water resources of a country are determined by a number of factors, including the amount of water received from precipitation, inflow and outflow in rivers and the amount lost by evaporation and transpiration (evaporation of water through plants). The potential for storage in aquifers and bodies of surface water is important in facilitating the exploitation of this resource by humans. These factors depend on geography, geology and climate.

Freshwater resources are continuously replenished by the natural processes of the hydrological cycle. Approximately 65 % of precipitation falling on land returns to the atmosphere through evaporation and transpiration; the remainder recharges aquifers, streams and lakes as it flows to the sea.

The average annual runoff for the member countries of the European Environment Agency (EEA) is estimated to be about 3100 km³ per year (314 mm per year). This is equivalent to 4500 m³ per capita per year for a population of 680 millions.

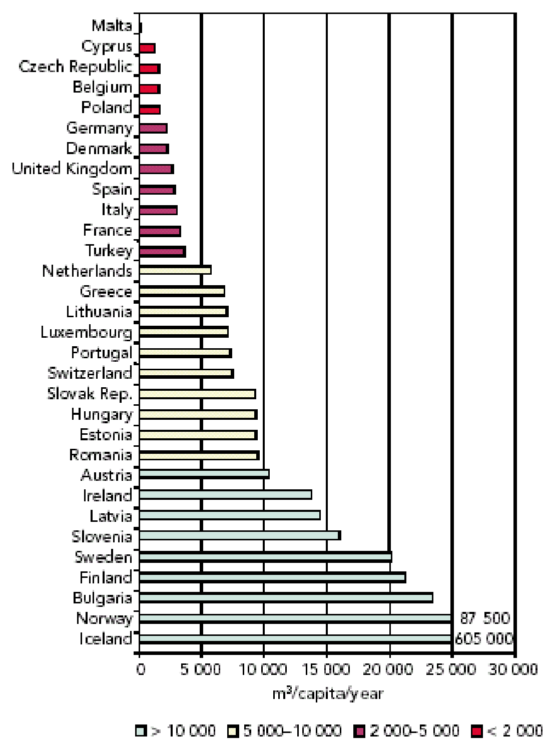


Figure 8: Annual Water availability per capita and country (Eurostat, 2001).

Sustainable use of the freshwater resources can only be assured if the rate of use does not exceed the rate of renewal. The total abstraction of a country or area must not exceed the net water balance (precipitation plus inflow minus evaporation and transpiration) and must guarantee a minimum river flow consistent with the Good Ecological Status (GES) that is supporting the typical biocoenosis of the water bodies.

Achieving the correct balance between use and renewal requires reliable quantitative assessment of the water resources and a thorough understanding of the hydrological regime. Available resources must be managed carefully to ensure that abstraction to satisfy the various demands for water does not threaten the long-term availability of water. Sustainability also implies management to protect the quality of the water resources, which may include measures such as preventing contaminants from entering the water, and maintaining river flows so that any discharges are sufficiently diluted to prevent adverse effects on water quality and ecological status.

At continental scale, Europe appears to have abundant water resources. However, these resources are unevenly distributed, both between and within countries. Once population density is taken into account, the unevenness in the distribution of water resources per inhabitant is striking.

A total of 12 countries have less than 4000 m^3/capita/year, while the Northern European countries and Bulgaria have the highest water resources per capita (Figure 8).

Population density also determines the availability of water per person and widely varies across Europe, from fewer than 10 inhabitants per km^2 in Iceland to over 300 per km^2 in the Benelux countries and San Marino and over 1000 per km^2 in Malta.

The total renewable freshwater resource of a country is the total volume of river runoff and groundwater recharge annually generated by precipitation within the country, plus the total volume of actual flow of rivers coming from neighbouring territories (Brouwer and Falkenmark, 1989). This resource is supplemented by water stored in lakes, reservoirs, snow, icecaps and fossil groundwater.

River runoff

In a long-term water balance, runoff is the amount of precipitation that does not evaporate, usually expressed as an equivalent depth of water across the area of the catchment. Stream-flow, in general terms, is the water within a river channel, usually expressed as a rate of flow passing a point, typically in m^3s^{-1}. A simple link between the two is that runoff can be regarded as stream-flow divided by catchment area, although in dry areas this does not necessarily hold, because runoff generated in one part of the catchment may infiltrate before reaching a channel and becoming stream-flow. Over short durations, the amount of water leaving a catchment outlet is usually expressed as stream-flow; over durations of a month or more, it is usually expressed as runoff.

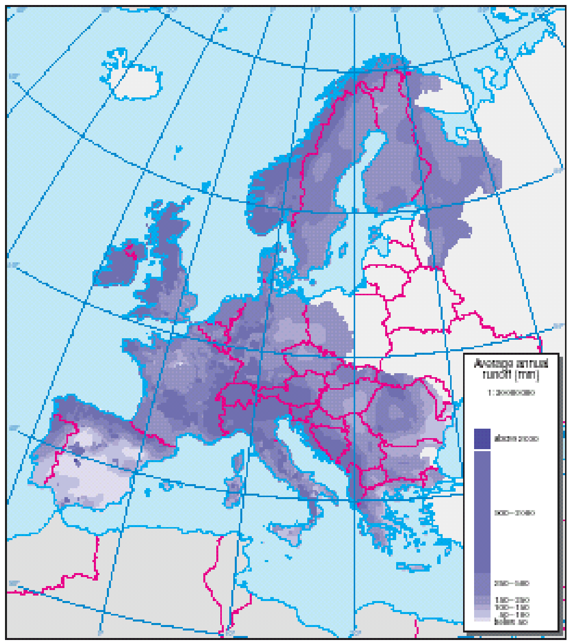
Renewable water resources include waters replenished yearly in the process of the annual water cycle; they are defined as the total volume of river run-off and groundwater recharge generated annually by precipitation, plus the total volume of actual flow of rivers coming from neighbouring territories. Thus, river runoff represents renewable water resources and constitutes the dynamic component of the total water resource (Figure 9).

Climatic and physical properties of the catchment, aggravated by human activities, such as river impoundment and land use changes, may lead to significant variations in seasonal flow regimes.

In general, trends in hydrological data are consistent with those identified for precipitation: runoff tends to increase where precipitation has increased and decrease where it has fallen over the past few years. Variations in flow from year to year have been found to be much more strongly related to precipitation changes than to temperature changes (e.g. Krasovskaia, 1995; Risbey and Entekhabi, 1996). There are some more subtle patterns, however. In large parts of Eastern Europe (Westmacott and Burn, 1997), a major—and unprecedented—shift in streamflow from spring to winter has been associated not only with a change in precipitation totals but more particularly with a rise in temperature:

precipitation has fallen as rain, rather than snow, and therefore has reached rivers more rapidly than before

There is also a considerable spatial variation in river flow across Europe. The average annual runoff in Europe very closely follows the pattern of average annual rainfall. Annual runoff is larger than 3000 mm in western Norway, and decreases to less than 25 mm in southern and central Spain and is about 100 mm over large part of Western Europe (Europe’s water: an indicator based assessment, EEA, 2003).



Source: European Environment Agency (1).

Figure 9: Long-term average annual runoff (in mm) in the European Union (EEA, 2003).

Groundwater

Groundwater represents the largest single source of freshwater in the hydrological cycle (about 95 % globally), larger in volume than all water in rivers, lakes and wetlands together. In general, groundwater is of good quality because of natural purification processes and very little treatment is needed to make it suitable for human consumption unless in the case of high natural occurrence of toxic substances (table 1).

Natural underground reservoirs can have an enormous storage capacity, much greater than the largest man-made reservoirs; they can supply “buffer storage” during periods of drought. In addition, groundwater provides base flow to surface water systems, feeding them all through the year. Thus, groundwater quality has a direct impact on the quality of surface waters as well as on associated aquatic and terrestrial ecosystems.

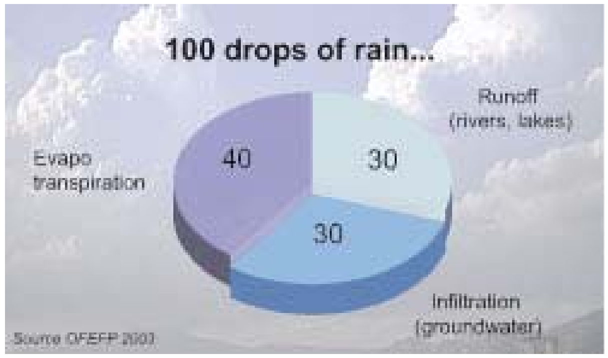


Figure 10: Precipitation and groundwater at the latitude of Switzerland (UNEP, 2004).

Region	(%)	Population served (millions)
Asia–Pacific	32	1 000 – 2 000
Europe	75	200 – 500
Central and South America	29	150
USA	51	135
Australia	15	3
Africa	NA	NA
World	-	1 500 – 2 750

Table 1: Estimated percentage of drinking water supply obtained from groundwater. Source: UNEP, 2004.

Groundwater represents the portion of precipitation that infiltrates into the land surface, entering the empty spaces between soil particles or fractured rocks; the larger the soil particles, the larger the empty spaces, and the greater the potential for water infiltration.
Groundwater systems are dynamic. Water is continuously in motion; its velocity is highly variable, ranging from a few meters per year to several meters per day. Many aquifer systems possess a natural capacity to attenuate and thereby mitigate the effects of pollution. The soil purifies the infiltrating water in three different ways. It serves as a physical filter retaining particles like a sieve. Secondly, pollutants undergo chemical conversion through contact with soil minerals. Furthermore, the surface layer of the soil supports intense microbial life; bacteria break down certain undesirable substances, neutralizing them.
Although groundwater is not easily contaminated, once this occurs, it is difficult to remediate. Therefore, it is important to identify which aquifer systems are most vulnerable to degradation. The replacement cost of a failing local aquifer will be high and its loss may stress other water resources serving as substitutes.

Groundwater abstraction

In some regions the extent of groundwater abstraction exceeds the recharge rate, thus leading to over-exploitation. In Europe, the share of groundwater needed at the country level to meet the total demand for freshwater ranges from 9 % up to 100 % (compare Figure 11). In the majority of countries, however, total annual groundwater abstraction has been decreasing since 1990. The vulnerability of an aquifer to overexploitation depends on its type, the climate, the hydrological conditions, and the uses of water. The rapid expansion in groundwater abstraction over the past 30 to 40 years has supported new agricultural and socio-economic development in regions where alternative surface water resources are insufficient, uncertain or too costly.
Over-abstraction leads to groundwater depletion, with consequences like landscape desertification, deterioration of water quality (e.g. saltwater intrusion), loss of habitats (e.g. wetlands), modification of river/aquifer interactions, and ground subsidence (see 1.3.4. and

Technical Report on Groundwater Management in the Mediterranean and the Water Framework Directive[7]).

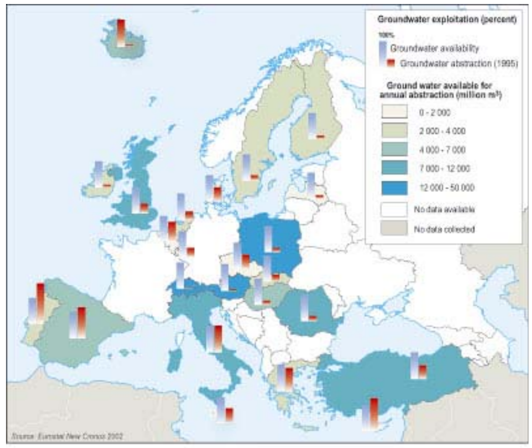


Figure 11: Groundwater resources and abstractions (Eurostat New Cronos, 2002).
Data for groundwater resources are long term annual average; data for groundwater abstractions refer to year 1995 except for Cyprus 1998, Ireland 1994, Netherlands 1996, Portugal 1998, Italy 1985, and Turkey 2000.

Groundwater and Water Framework Directive

Strategies to prevent and control pollution of groundwater are covered by Article 17 of the WFD, which requires the establishment of criteria for assessing good groundwater chemical status, the identification of significant and sustained upward trends and for the definition of starting points for trend reversals. Article 17 requests the European Commission to present a proposal based on the above requirements. This new Groundwater Directive[8], which complements the WFD, sets up criteria for the evaluation of good groundwater chemical status (based on EU-wide quality standards, groundwater threshold values and WFD criteria), for the identification and reversal of significant and sustained upward trends in pollutant concentrations (taking account of threshold values to be developed by Member States at the national, regional or local level) and provides additional requirements concerning the prevention or limitation of indirect discharges.

The Groundwater Directive ensures that groundwater quality is monitored and evaluated across Europe in a harmonised way. The proposed approach for establishing quality criteria takes into account the local characteristics and allows for further improvements. It represents a proportionate and scientifically sound response to the requirements of the Water Framework Directive related to the assessment of the chemical status of groundwater and the identification and reversal of significant and sustained upward trends in pollutant concentrations.

Guidance and technical documents are being prepared by the Working Group C of the WFD Common Implementation Strategy (WFD-CIS WG-C) on a number of issues such as groundwater status assessment, groundwater-surface water interaction, over pumping and salinisation, monitoring, protected areas and prevention and limitation of pollutant inputs into groundwater[9].

Aquifer recharge

[7] http://www.emwis.net/topics/groundwater/Mediterranean_Groundwater_Report_final_150207.pdf

[8] Directive 2006/118/EC of the European Parliament and of the Council of 12 December 2006 on the protection of groundwater against pollution and deterioration

[9] http://ec.europa.eu/environment/water/water-framework/groundwater/scienc_tec/cis/index_en.htm

Natural aquifer recharge (from rain or surface water infiltration) is vital in order to maintain the groundwater and to replenish the discharges from the aquifer with a good quality water resource, but in many cases is quite impossible to grant a sustainable groundwater level only considering natural recharge. In many areas of the world, aquifers that supply drinking-water are being used faster than they recharge. Not only does this represent a water supply problem, it may also have serious health implications. Moreover, in coastal areas, aquifers containing potable water can become contaminated with saline water if water is withdrawn faster than it can naturally be replaced. The increasing salinity makes the water unfit for drinking and often also renders it unfit for irrigation. To remedy these problems, some authorities have chosen to recharge aquifers artificially with treated wastewater, using either infiltration or injection. Aquifers may also be passively recharged (intentionally or unintentionally) by septic tanks, wastewater applied to irrigation and other means. Artificial recharge is the planned, human activity of augmenting the amount of groundwater available through works designed to increase the natural replenishment or percolation of surface waters into the groundwater aquifers, resulting in a corresponding increase in the amount of groundwater available for abstraction.

Reservoir stocks

The use of storage reservoirs helps to overcome the uneven distribution of natural water resources. Runoff in the wet season can be held back and used in the dry season (seasonal regulation), and water available in wet years can be stored and used in dry years (interannual regulation). The beneficial aspects of reservoirs in safeguarding water resources and supplies have to be balanced against the significant impacts that their construction and subsequent operations have on natural landscapes and ecosystems.

The predominant functions of reservoirs in Europe are storage for hydroelectric power production, public water supply, and irrigation. Water is not always available to meet demands. In particular, water for urban use must be guaranteed and irrigation demands often need to be met during the dry season, when river discharges are at their annual lowest level. Water storage by reservoirs helps to overcome this temporal unavailability of freshwater resources. In Europe, approximately 13 % of mean annual runoff is stored by dams. It represents a significant increase in the standing stock of natural river water, with residence times in individual reservoirs of less than one day to several years.

The countries with the highest percentage of stored water volume in relation to their annual renewable freshwater resources (over 20 %) are Turkey, Spain, and Cyprus. These countries also use the highest percentage of their resources for irrigation. This activity demands the largest water volumes in the driest seasons, requiring winter storage. Spain and Cyprus are considered to be water stressed, whilst Turkey has low water stress (see figure 2, Water Exploitation Index). In many countries such as Austria, Finland, France, Greece, Ireland, Italy, Norway, Portugal, and Sweden the majority of large reservoirs are used for hydropower production. In particular, the primary purpose of major reservoirs in Sweden and Norway is almost exclusively for hydroelectricity (EEA, 1999).

Non-conventional resources

With increasing pressure on natural freshwater in parts of the world, other sources of water are growing in importance. These non-conventional sources of water represent complementary supply sources that may be substantial in regions affected by extreme scarcity of renewable water resources. Such sources are accounted for separately from natural renewable water resources. They include:

- the production of freshwater by desalinization of brackish or saltwater (mostly for domestic purposes),
- the reuse of urban or industrial wastewaters (with or without treatment), which increases the overall efficiency of use of water (extracted from primary sources), mostly in agriculture

but increasingly also in industrial and domestic sectors. This category also includes agricultural drainage water.

Desalinization

Initially sea-water desalinization technologies were based on distillation; hence energy consumption was very high. The development of more efficient technologies (such as inverse osmosis) has reduced the cost of desalinization considerably (below 1 €/m^3). However, this technique still tends to be considerably more expensive than supply from conventional sources (surface water and groundwater). Desalinization of sea water or brackish groundwater is therefore mainly applied in places where no other sources are available. Sea-water desalinization in Spain accounts for about 0.22 km^3/year. Although this volume is small in comparison to total renewable water resources in the country (111 km^3/year), it represents a significant share of resources in the areas where this technology is applied (mainly the Canary and Balearic Islands). In Greece, five desalinization plants are in operation, all of them on islands. However, desalinization can produce the degradation of coastal habitats like Posidonia sea-grass if the concentrated salt is not released adequately.

Water reuse

Water reuse is the use of wastewater or reclaimed water from one application such as municipal wastewater treatment for another application such as landscape watering. The reused water must be employed for a beneficial purpose and in accordance with applicable rules (such as local ordinances governing water reuse). Factors that should be considered in an industrial water reuse programme include (Brown and Caldwell, 1990):

- identification of water reuse opportunities,
- determination of the minimum water quality needed for the given use,
- identification of wastewater sources that satisfy the water quality requirements,
- determination of how the water can be transported to the new use.

In terms of quantitative water resources management, the reuse of wastewater or reclaimed water is beneficial because it reduces the demand for surface and groundwater. The greatest benefit of establishing water reuse programmes might be their contribution in delaying or eliminating the need to increase potable water supply and the capacity of water treatment facilities, and in reducing the costs of long sea outfall pipes to dispose of wastewater.
Main applications of this technique can be found for irrigation in agriculture, parks, recreational areas, golf courses, etc. Usually, simplified water treatment is carried out, in order to guarantee minimum quality standards of the water to be reused. Few studies and data about the reuse of wastewater are available, and further research is needed to assess the long-term effects of irrigation with treated wastewater on soils and agriculture.
In France, wastewater reuse has become a part of regional water resources management policies. It is practised mostly in the southern part of the country and in coastal areas, compensating local water deficiencies. In Portugal, it is estimated that the volume of treated wastewater is around 10 % of the water demand for irrigation in dry years, and that between 35'000 ha and 100'000 ha could be irrigated with treated wastewater. In Spain, the total volume of wastewater reclaimed amounts to 0.23 km^3/year, being used mainly for irrigation in agriculture (89 %), recreational areas and golf courses (6 %), municipal use (2 %), environmental uses (2 %), and industry (1 %)[10].

Water recycling

[10] For more information on waste water reuse potential, technologies, etc. see results of AQUAREC project http://www.aquarec.org/

Reuse of water for the same application for which it was originally used. Recycled water might require treatment before it can be used again.

Rainwater harvesting

For centuries, people have relied on rainwater harvesting to supply water for household, landscape, livestock, and agricultural uses. Before large centralized water supply systems were developed, rainwater was collected from roofs and stored on site in tanks known as cisterns. A renewed interest in this approach has emerged due to the escalating environmental and economic costs of providing water by centralized water systems or by well drilling, and the potential cost and energy savings associated to rainwater collection systems which are a source of water.

1.3.3. Background of water demand

Various concepts are used to describe the diverse aspects of water use. Water abstraction is the quantity of water physically removed from its natural source. Water supply refers to the share of abstraction which is supplied to users (excluding losses in storage, conveyance and distribution), and water consumption means the share of supply which in terms of water balance is actually used (as evaporation) whilst the remainder is reintroduced into the source of abstraction.

The term "water demand" is defined as the volume of water requested by users to satisfy their needs. In a simplified way, it is often considered equal to water abstraction, although conceptually the two terms do not have the same meaning. Water demand estimations should be clearly associated to different prices of water.

Agricultural water use

Over the past decades the trend in agricultural water use has, in general, been upwards, due to increasing use of water for irrigation. However, during recent years in several countries, the rate of growth has slowed down. The total water abstraction for irrigation in Europe is about 105'068 Hm^3/year (Hm^3 = cubic hectometre = 1 million cubic metres). The mean water allocation for agriculture decreased from 5499 to 5170 m^3/ha/year between 1990 and 2001.

Reforms of the Common Agricultural Policy of the European Union will lead to changes in the types of crop being cultivated, the area irrigated, and the amount of water used. Two opposing trends can be distinguished. On the one hand, if production is reduced, the demand for production inputs such as water is bound to diminish. On the other hand, there might be a switch towards more profitable crops, which at least in southern Europe frequently require irrigation.

Domestic use

The total water use for urban purposes in Europe is 53'294 Hm^3/year which amounts to 18 % of total abstraction and to 27 % of its consumptive uses. Between 1990 and 2001, urban use per capita has decreased and many changes have occurred, influencing the patterns of urban water use : increasing urbanization, changes of population habits, use of more efficient technologies and water saving devices, alternative sources of water (desalinization, indirect and direct wastewater reuse), increasing metering, and use of economic instruments such as water charges and tariffs. Connection of population to water supply systems has also increased, especially in Mediterranean countries.

The water required for drinking and other domestic purposes is a significant proportion of the total water demand. The proportion of water for abstracted urban use ranges from about 6.5 % in Germany to more than 50 % in United Kingdom.

Population distribution and density are key factors influencing the availability of water resources. Increased urbanization concentrates water demand and can lead to the overexploitation of local water resources. Higher standards of living are changing water demand patterns. This is mainly reflected in increased domestic water use, especially for personal hygiene. Most of the European population has indoor toilets, showers and/or baths for daily use. Most of the water use in households is for toilet flushing (33 %), bathing and showering (20 % - 32 %), and for washing machines and dishwashers (15 %). The proportion of water used for cooking and drinking (3 %) is minimal compared to the other uses.

Industrial water use

The total water use for industry in Europe is 34’194 Hm^3/year which amounts for 18 % of its consumptive uses. Between 1990 and 2001, the industrial use has decreased consistently.
Over the period considered, different changes have occurred and have influenced the industrial water use: decline of industrial production, use of more efficient technologies with lower water requirements and use of economic instruments (charges on abstractions and effluents).
The biggest industrial water users are the chemical industry, the steel, iron and metallurgy industries, and the pulp and paper industry, although in most European countries industrial abstractions have been declining since 1980. In Western Europe this is due, primarily, to economic restructuring with closures in water-using industries such as textiles and steel, and a move towards less water-intensive industries. Technological improvements in water-using equipment and increased recycling and re-use have also contributed to the decline. In Eastern Europe, abstractions seem to have diminished due to the serious decline in industrial activity across the whole sector.
Generally, pricing mechanisms have been used more intensively to encourage water use efficiencies in the industrial sector than in the household and agricultural sectors, as companies will adopt water-saving technologies faster, if costs can be reduced. Charges for the discharge of contaminated water into the sewerage network are also an important incentive for industries in order to improve process technologies and to reduce the amount of water used and discharged.

Energy water use

Water abstracted for energy production is considered as a non-consumptive use and accounts for about 30 % of all the uses in Europe. Western European and Accession Countries are the largest users of water for energy production, in particular Belgium, Germany and Estonia where more than half of the abstracted water is used for energy production.
In general, the quantities of water abstracted for cooling by far exceed those used by the rest of industry. However, cooling water is generally returned to the water cycle unchanged, except with an increase of temperature and some possible contamination by biocides.

Tourism

In the Mediterranean region, about 135 million tourists (international and domestic) stayed along the coasts in 1990, representing more than half the total tourism in all Mediterranean countries and doubling the coastal population.
Tourism places a wide range of pressures on local environment. The impact on water quantity (total and peak) depends on water availability in relation to the particular timing and location of the water demand from tourism and on the capability of the water supply system to meet peak demands. The intensity of the natural resources used by tourism can conflict with other needs, especially in regions where water resources are scarce in summer,

and with other sectors of economic development such as agriculture and forestry. Uncontrolled tourism development, typically like in the past, has led to a degradation of the quality of the environment, particularly in coastal and mountainous zones.
Tourist water use is generally higher than water use by residents. A tourist consumes about 300 l/ day; European household consumption is about 150 - 200 l/day. In addition, recreational activities such as swimming pools, golf and aquatic sports contribute to the pressure on water resources.

Network leakages

The reduction of leakage (both real and apparent) is an essential measure for water resources conservation and for the achievement of a good water balance at river basin scale. Water losses due to network leakage include technical and economical aspects, and the importance of this issue is shared at international level. Accordingly, it is useful to agree upon a common terminology. The following definitions have been stated by the International Water Association (IWA Bluepages, 2000):

- Water Losses

Water losses of a system are calculated as the difference between the system input volume and the authorised consumption. Water losses can be considered as a total volume for the whole system, or for partial systems such as raw water mains, transmission, or distribution. In each case the components of the calculation would be adjusted accordingly. Water losses consist of real and apparent losses.

- Real Losses

Real losses are physical water losses from the pressurised system, up to the point of customer metering. The volume lost through all types of leaks, bursts, and overflows depends on frequencies, flow rates, and average durations of individual leaks.

- Apparent Losses

Apparent losses consist of unauthorised consumption (theft or illegal use), and all types of inaccuracies associated with production metering and customer metering. Under-registration of production meters and over-registration of customer meters lead to under-estimation of real losses. Over-registration of production meters and under-registration of customer meters lead to over-estimation of real losses.

- Non-revenue Water

Non-revenue water is the difference between the system input volume and billed authorised consumption.

Water leakage includes:

- losses due to pipeline breakage or damages,
- losses due to joints damages, especially in old and extended networks,
- losses in users connections,
- losses and surmounting in water reservoirs.

The main leakage indicators internationally used are:

- % of input volume: non-revenue water divided for the system input volume, multiplied by 100,
- specific water loss (m^3/day/km): the leakage volume divided by the length of mains and by the reference time,
- losses for number of service connection, referred to a specific reference time (day, hour, etc).

The IWA proposes also a new leakage indicator: the Infrastructure Leakage Index (ILI). This index can be used in order to provide additional insight into technical comparisons, as it takes into account many of the key influences on real losses (number of service connection, length of service connections, etc.) and separates aspects of infrastructure management from aspects of pressure management.

1.3.4. Impact and assessment of imbalances

Driving Forces

Water quality and quantity are threatened by human activities that cause pressures on the environment, including urbanization, tourism, industry and agriculture (table 2).

Table 2: Driving forces and impacts (UNEP - Freshwater in Europe, 2004)

Driving Forces	Impact
Urbanization	Increasing urban population causes substantial pressures on surface and groundwater. More than two-thirds of Europe's population lives in urban areas and the rate of urbanization is, in particular, increasing in Central and Eastern Europe, while in Western Europe it has stabilized.
Industry	Industrial pressures involve: high water demand for cooling and cleaning purposes; pollution with potentially toxic inorganic and organic substances (e.g. organic matter, metals, chlorinated hydrocarbons, nutrients…); disposal or dumping of sludge and waste, and inadequate containment of old industrial sites; accidents during production and transport. Further pollution arises from emissions to air, mainly from the combustion of fossil fuels, which initiate a process of acidification.
Tourism	Tourism causes very high pressures especially on groundwater, because of the additional water demand during seasons when the groundwater situation may already be rather critical. Waste and sewage from this sector represent another potential source of water pollution.
Agriculture	Agriculture causes high pressure and can produce its depletion due to over-abstraction. The legacy of the agricultural intensification of the post-war years is still present, and it is widely predicted that groundwater will continue to be contaminated with nitrate for several decades.

Over-exploitation effects

- Groundwater quality:

  Continuous groundwater over-exploitation can cause isolated or widespread groundwater quality problems. Over-abstraction causes a decrease in groundwater level which can influence the movement of water within an aquifer. Significant draw-downs can cause serious quality problems. One of these changes is displacement of the freshwater/saltwater interface, causing active saltwater intrusion.

- Saltwater intrusion:

  Large areas of the Mediterranean coastline in Italy, Spain, and Turkey have been affected by saltwater intrusion. The main cause is groundwater over-abstraction for public water supply, followed by agricultural water demand and tourism-related abstractions. Irrigation is the main cause of groundwater overexploitation in agricultural areas. An example is the Greek Argolid plain of eastern Peloponnesus, where it is common to find boreholes 400 m deep contaminated by salt water intrusion.

- River-aquifer interactions:

  Aquifers can exert a strong influence on river flows. In summer, many rivers are dependent on the groundwater base flow contribution for their minimum flow. Lower groundwater levels due to over-exploitation may, therefore, endanger river dependent ecological and economic functions, including surface water abstractions, dilution of effluents, navigation and hydropower generation.

- Wetlands:

  Water abstraction in areas near wetlands can be a serious problem, as groundwater pumping usually lowers the groundwater table, causing an extended, deeper unsaturated zone. This can severely damage wetland ecosystems which are very sensitive to minor changes in water level.

- Ground subsidence:

  Heavy draw-down has been identified as the cause of ground subsidence or soil compaction phenomena in some parts of Europe, notably along the Veneto and Emilia-Romagna coasts, the Po delta and particularly in Venice, Bologna and Ravenna in Italy.

Pollution effects on groundwater

Pollution of a water body occurs when an impurity (micro-organism or chemical) is introduced by or as a result of human activities, creating an actual or potential danger to human health or the environment when present at high concentrations. Europe's groundwater is polluted in several ways: nitrates, pesticides, hydrocarbons, chlorinated hydrocarbons, sulphate, phosphate and bacteria. Some of the most serious problems are caused by nitrates and pesticides (figures 12 and 13).

As groundwater moves slowly through the ground, the impact of human activities can last for a relatively long time. This makes pollution prevention very important for addressing groundwater issues.

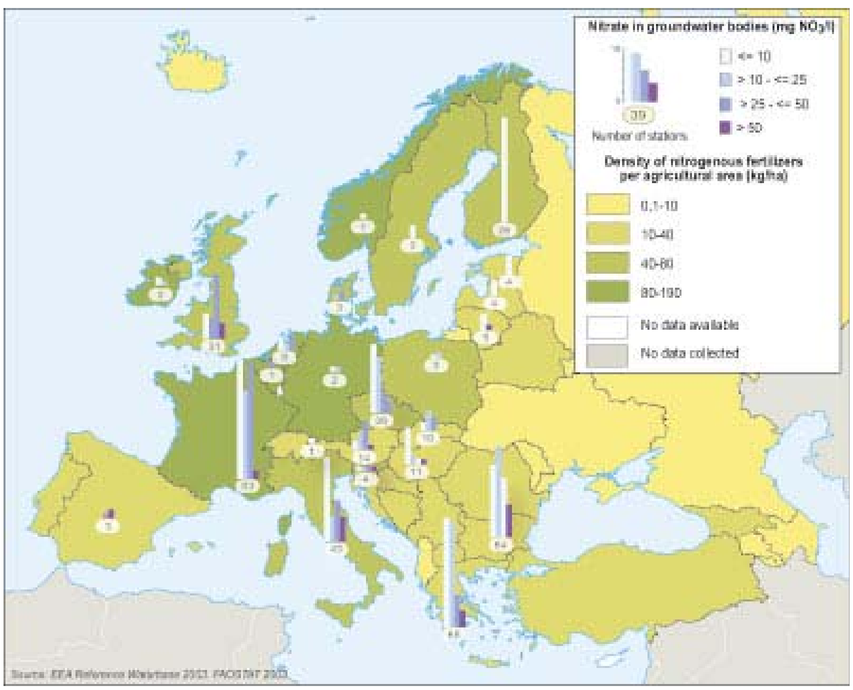


Figure 12: Nitrate in Groundwater Bodies (FAOSTAT – 2003).

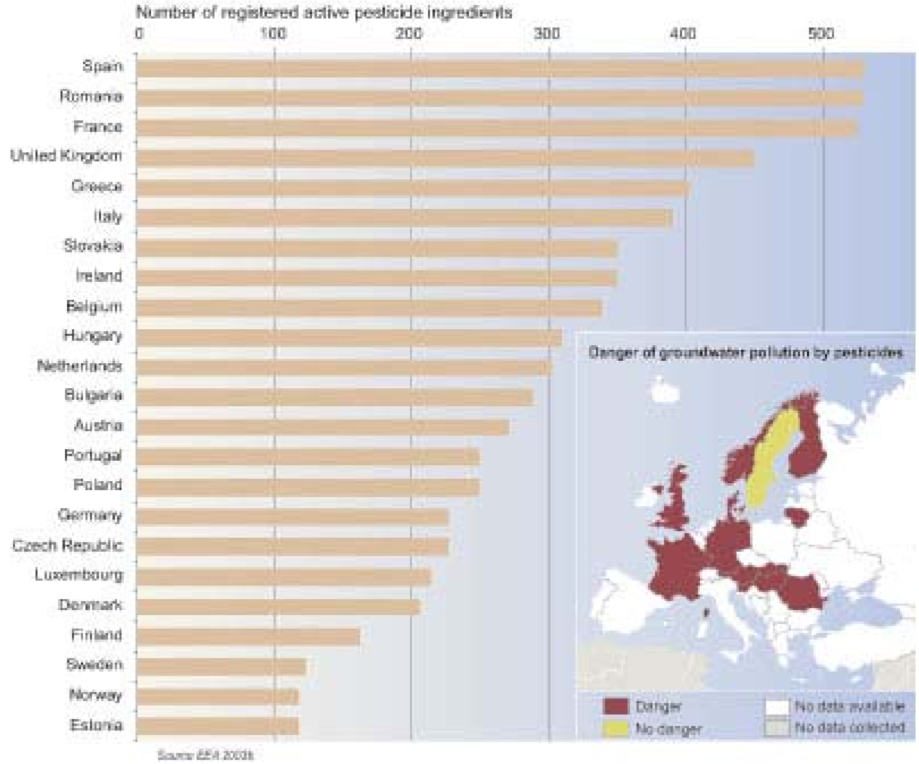


Figure 13: Number of registered active pesticide ingredients (EEA – 2000).

Characterization of drought/drought definition

Contribution from Palestinian hydrologic Group

The past few years have witnessed annual precipitations below the average in Palestine. In 1998/99, the rainfall record in the winter was the minimum in the past 100 year long history of rainfall records. This drought has led to water quality deterioration, drop in the groundwater levels and decline in spring discharge. Accordingly, water shortage has become very acute and available supply falls short in meeting demand. Under the foreseeable future scenarios of population growth and development needs, this water shortage is expected to intensify. The average population growth rate is estimated at 4%, which, means that the population is expected to double in the coming two decades. (Rabi et.al, 2003a). In an attempt to quantify the characteristics of the 1998–1999 droughts and assesses its hydrologic impact on the Eastern groundwater basin in the West Bank/Palestine, hydrologic droughts were defined as the decrease in spring discharge and the drop in water levels. Most of the springs in the West Bank are affected by seasonal changes in rainfall quantities. When the relationship between the rainfall depths and spring discharge was investigated further, it was found that the adjusted correlation improves once rainfall of the previous years is taken into consideration. This means that the amount of spring discharge in any particular year is a function of rainfall during the same year, as well as that of the past years. The best correlation was found to be a three-year model. The analysis of groundwater level–rainfall depth relationship showed that the best correlation was a one-year model. However, in order to recommend drought management plans, further monitoring and hydrologic modelling is required.

In another attempt to conduct drought analysis in the West Bank and to assess the impact of climate change, a physically based model has been used to assess the water balance components along with possible climatic scenarios (Carmi et al, 2004). The possible increased rainfall intensity coupled with an increase in extreme events, and an overall reduction in precipitation will lead to the increased soil erosion, runoff and salinization. This in turn will cause loss of biodiversity and increase desertification. Palestine already suffers from water shortage and if the available quantities are polluted the situation will be more critical and will likely cause a rise in the incidence of water borne diseases. On another level, the increased water stress will increase the likelihood for water resource conflicts in the region. This will also increase abstraction from groundwater and will deplete the storage. Although, assessments have been made in relation to the particular climate scenario used, yet they are expected to serve as a guideline for future research only. The development of non-conventional water resources for agriculture and artificial recharge and sustainable use of water, along with water conservation practices are among the possible adaptation measures adopted.

2. CHAPTER II: DROUGHT PLANNING AND MANAGEMENT[11]

2.1. Responding to drought management challenges

The purpose of this chapter is to provide Mediterranean countries with a framework for effective and systematic approach to prevent and/or minimize the impacts of drought on people. The Mediterranean region exemplifies many other drought-prone regions with rapidly expanding populations that are placing increased pressure on already limited water supplies.

Drought planning and management includes activities and actions taken by any interested individual or collective group. The Meda-Water project MEDROPLAN has synthesised academic and policy aspects of drought planning and developed drought management guidelines (the "guidelines" from now on) that appeal to a broad audience, the non-technical users and especially oriented to the support of policy making. The adaptive and dynamic character of the Guidelines presented in this chapter includes the following aspects:

- Aim to provide a methodological framework by using examples that may be followed to develop drought management plans in a range of situations.
- Information intending to complement the ongoing regional and country water basin planning efforts and the ongoing agricultural policy initiatives.
- Consideration of both long term and short term measures that are to be used to prevent and mitigate the effects of drought.
- Design broad enough to incorporate new criteria for establishing priorities as societies change or as scientific and technological aspects of drought management improve.
- 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.

2.2. Components of drought planning and management

Figure 14 summarises the main components of drought planning and management that will be described in the following sections. It is based on the Medroplan guidelines:

1. The planning framework
2. Organizational component
3. Methodological component
4. Operational component
5. Public review component
6. Examples of the application

[11] We gratefully acknowledge the Meda-Water for support and the participants and stakeholders in the Project MEDROPLAN for their valuable input http://www.iamz.ciheam.org/medroplan/

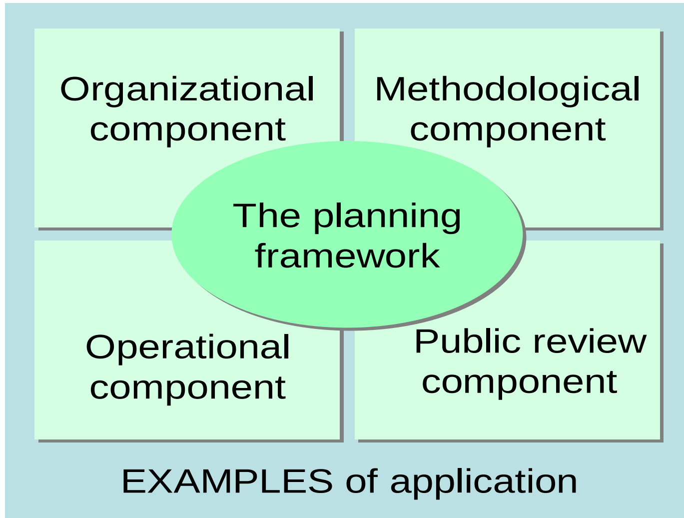


Figure 14 Components of drought planning and management

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 planning framework guides the user of the Guidelines to define the planning purpose and process, establish 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 to:

- Compile and provide the most comprehensive information about how society responds to drought and establish the linkages among the stakeholders
- Coordinate with the various institutions to avoid conflict, duplication, and expedite the administrative and legal process
- Provide responsible and timely public information
- Encourage water and energy conservation
- "Declare drought"

The **methodological component** presents the scientific approach to risk evaluation, including characterization of drought episodes, development of indicators of risk in hydrological and agricultural systems, and analysis of the role of economic instruments and groundwater for risk mitigation. This component also includes the description of an integrated method for evaluating social vulnerability based on indicators that include the capacity to anticipate, cope, and respond to drought.
Drought's characterisation and risk and vulnerability analysis are complex and there are a wide range of methods applied. Each method has its own merit and they are usually supportive of each other. A combination of methods is usually most rewarding.

The **methodological component** provides a framework to:

- Compile and provide the most comprehensive technical and scientific approaches to drought characterization, development of indicators of risk in hydrological and agricultural systems
- Define the methods used for risk management in the context of Mediterranean climate and social characteristics: including economic instruments, application of technology, and groundwater use, etc.

- Define the academic methods for evaluating social vulnerability based on indicators that include the capacity to anticipate, cope, and respond to drought.
- Encourage technical studies to strengthen the use of indicators and the declaration of drought

The **operational component** identifies both the long and short term activities and 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 several aspects:
- Preparedness and early warning (permanent measures)
- Establishing priorities to be respected during water scarcity situations
- Thresholds defined by drought indices and indicators (physical and social)
- Evaluating the process to implement the actions
- Defining the actions

The Guidelines includes examples of the application of the planning framework to specific situations (Figure 15) in order to show how the various components and methodologies can be developed and applied to develop drought management plans.
The tutorial guides the web-user to find and select the relevant information in the different aspects of developing a drought management plan, and provides examples of use of the methods and models available and applied in the examples of application.

The **public review component** tests a draft proposal for a drought management and preparedness plan by means of dissemination activities and public multi-stakeholder dialogue.
Drought management plans are not static products, they are always in progress. As technologies evolve, new programs are developed, and institutional responsibilities change, drought management plans have to be revised and therefore all components need to be considered dynamic (Figure 15).
However the proposed drought plan is the result of more than three years of research and it should be considered as an integrated drought plan, which takes into account almost every aspect of mitigating drought for the time being. It is true, though that from time to time it should be reviewed and probably edited and updated.

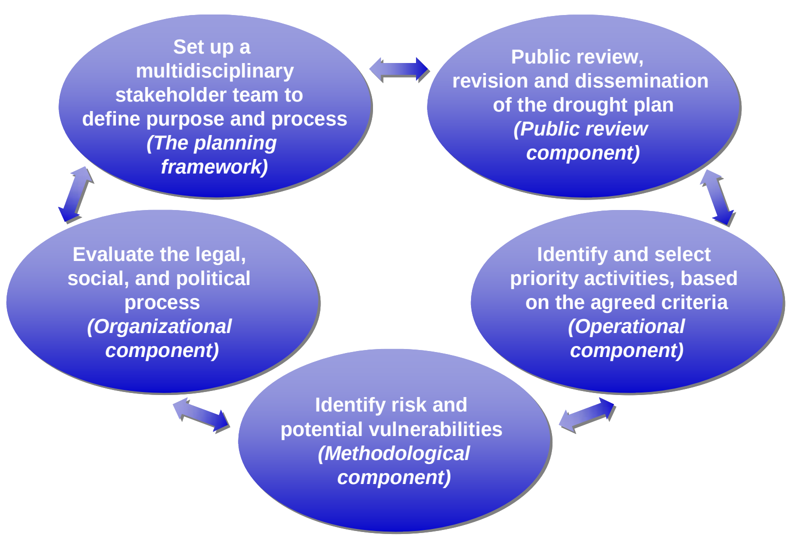


Figure 15: Development and revision of the guidelines for drought management plans

The **examples of application** are a key component since:

- 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 drought management and preparedness planning.
- Existing valuable information and knowledge: water supply management under scarcity; development of drought response procedures.
- The Guidelines are not prescriptive, rather a range of options is provided based on real case studies.

2.3. The planning framework

2.3.1. Defining the planning purpose and process

This component 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.
It is necessary to define a purpose since 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 focus 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.

2.3.2. 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 feeds into 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?

Evaluation of the incentives and means for engaging different stakeholders groups
Analysis of the realism of engaging stakeholders in the decision making process
Translation of complex models into transparent products that and provide insight to individual users

Do all stakeholders speak the same language?

Because the purpose of the Guidelines is to reach a broad number of stakeholders, it is essential to establish a common language from the onset. This goal is attained by discussing and adopting a glossary of terms and by applying those terms to specific examples brought by the stakeholders groups.

2.4. Organizational component

2.4.1. Overview

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 the various institutions to avoid conflict, duplication, and expedite the administrative and legal process
- Provide responsible and timely public information
- Encourage water and energy conservation
- "Declare drought"

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 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. To understand the national institutional regime is a key factor for establishing effective and integrated drought management plans that incorporate monitoring, public participation, and contingency planning (Iglesias and Moneo, 2005).

This component provides a common methodology for analysing the organizations and institutions relevant to water scarcity and drought management.

2.4.2. The geographical unit

The geographic unit, or spatial extent of the drought plan, defines both the bio-physical risks to be considered, the stakeholders affected and their responses, and the organizations and institutions responsible for planning. The river basins, water catchment systems, and water projects, are appropriate units 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 priority of users or right holders according to each situation, can approve works and projects needed to solve emergent scarcity problems, and can create Water Exchanging Centres, through which right holders can offer or demand use rights in periods of droughts or severe water scarcity situations.

The human dimension of drought management in the Mediterranean might not stop at the regions' boundaries. There is the potential for more pronounced water conflicts with neighbouring regions (i.e. transboundary issues in shared surface waters and aquifers) and demographic shifts due to the collapse of agricultural activities in some areas.

2.4.3. The stakeholders

Each geographical unit should have its own stakeholders system that has to be carefully diagnosed. Table 3 shows an example of stakeholder diagnosis in Mediterranean regions, stressing the relation of stakeholders with drought.

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 minimise 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 Company 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 Agency. 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 Agency or private company. 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 Agency	Use of data to analyse risk	Capacity to develop early warning systems
9. Ministries of Agriculture, Environment, Water, Tourism, Industry	Government Agency. Participate in drought committees	Implementation of mitigation policies	Coordination and capacity to revise legislation
10. Agricultural Insurance companies	Private- public Agency	Develop adequate insurance products	Revision of insurance products
11. Rural lending institutions or banks	Government Agency or private	Forecasting extraordinary financial resources	Revision of financial products
12. Research and education institutions	Private- public institution	Develop adequate academic knowledge on risk analysis, adaptation and technology	Improvement of international academic knowledge

Stakeholder	Participation	Expectations	Adaptive capacity
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

Table 3: Stakeholder identification and participation in drought management

2.4.4. The legal and institutional framework

The social and hydrological context of the Mediterranean have resulted in a complex institutional framework, and highlighted the importance of stakeholder involvement and awareness raising 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.

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 and disposing of meteorological and hydrological data,
Drought preparedness and mitigation and/or on water management.
The analysis aims to provide insights to the following key questions:
Are the set of organisations 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 networks?
What is the degree of influence and dependence of the stakeholders' decisions on the institutions' core themes?

Methodology

Although the objectives of the Guidelines are not directly focused on the institutional analysis per se, it is important to understand the concept, to identify them and map them to ensure the relevance of subsequent drought management analysis. The methodology developed comprises five main tasks:

Elaborate a mental model of organisations and institutions in each country and describe the institutional and legal frameworks.
Collect additional information by interviews and / or other dialog methods. The interview should include "problem analysis" (i.e., what actions did your institution take during a historical drought in a specific year?) and identification of 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 decision within the institution and within the hierarchical structure in each country.
Discussion of the challenges and opportunities to improve drought management.

No single management action, legislation or policy can respond to all aspects and achieve all goals for effective drought management. Multiple collaborative efforts are needed to integrate the multidimensional effects of drought on society. Figure 14 shows a schematic view of the methodology applied in MEDROPLAN. Examples of application and results are provided in each individual case study.

Expected outcome

Each country has applied the methodology in order to get:
An explicit description of institutions and organizations with competence in water policy and administration, planning, decision making, operation of water supply systems and drought preparedness, and emergency action with particular emphasis in municipal and irrigation water supply.
An explicit description of the linkages and hierarchical relations among the organizations and institutions.
Information on existing drought preparedness and management plans.
Documentation on the institutional experience of 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.

2.5. Methodological component

2.5.1. Overview

The need of a methodological component

A methodological component is needed to define the methods used for risk management including:

- Comprehensive technical approach to characterise drought risk and social vulnerability based on indicators that include the capacity to anticipate, cope, and respond to drought.
- Establish the planning phases and the thresholds for indicators to be used to declare drought.

Defining the technical approach

The methodological component defines the technical approach and the type of studies to be carried out in order to establish the linkage between the drought phenomena and the management actions. This includes:

- Drought characterisation
- Risk and vulnerability analysis (diagnostic)

Aspects	Items of special interest	Key considerations for analysis
Data and information systems	• Bio-physical (hydro-meteorological, agricultural, etc) • Socio-economic	• Availability • Reliability of data collection and processing
Specific drought related	• Specific legal provisions for drought preparedness	**Reactive capacity**: • Time response after declaration of

action plans	• Risk-sharing mechanisms (i.e., insurance) • Existence of an drought management committee • Contingency plan • Budgetary provisions • Social participation	drought • Coordination • Mobilisation of financial resources • Outreach • Policy implementation • Ability to anticipate costs and effects
Drought related initiatives not included in specific drought plans	• General legal provisions related to drought • Policy initiatives: level and financial support	**Scope**: • Sectoral levels • Geographical level • Social groups • Indirectly related sectors • Special target groups **Social learning process**: • Drawn lessons from past drought experience • Research and Development • Ex –post evaluations • Preparation of remediation and alleviation plans • Participation in international initiatives/projects

Table 4: Expected outcomes from the institutional analysis related to operational performance

The methodological component presents the scientific approach to risk evaluation, including characterization of drought episodes, the development of indicators of risk in hydrological and agricultural systems, and analysis of the role of economic instruments and groundwater for risk mitigation. This component also includes the description of an integrated method for evaluating social vulnerability based on indicators that include the capacity to anticipate, cope, and respond to drought.

Drought's characterisation and risk and vulnerability analysis are complex since each drought is different and the effects depend on the social and technical characteristics of the system. Therefore there are a wide range of methods that can be applied for analysis ranging from simple indicators of the physical phenomena to complex multi-variate models that describe social response. Each method has its own merit and they are usually supportive of each other. A combination of methods is usually most rewarding. It is important to convey to the stakeholders that any method for analysing risk involves the concept of probability.

Vulnerability refers to the characteristics of a group in terms of its capacity to anticipate, cope with, resist and recover from the impact of drought. Vulnerability represents the internal component of risk and can be described by a combination of economic, environmental, and social factors.

Producing technical information that is understood by stakeholders

The proposed methodological component is based on two main requirements: objectivity and simplicity. 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 difficult to understand and may not be trusted by affected users. 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.

2.5.2. Drought characterisation

Objectives

Provide the methodology to be applied for the characterisation of meteorological and hydrological droughts and water scarcity.

Methods

Drought characterisation is complex and there are a wide range of meteorological or hydrological indices or indicators (see chapter I). 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.

Evaluation of the indices of meteorological and hydrological drought: they should be calculated from data available from actual data collection systems; have a priori and direct relation with vulnerable social, economic and environmental systems; and should be able to be used for predictions and early monitoring systems.

The methods should include a discussion of the sources, scales and reliability of the data used in the analysis.

Expected outcome

The expected outcome is the characterization (understanding of the system) of the meteorological and hydrological drought periods in the historical record in each geographical units.

The correct drought characterisation is valuable for providing decision makers with a measurement of the abnormality of recent weather variability and its effects on water scarcity for a region. Actions are taken in response to drought declaration, therefore this methodological component is crucial for all stakeholders.

Drought indices

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 reduce drought impacts.

- Drought indices are not a goal, but a mean to identify and analyze droughts
- Indices computed are “moderately” complex
- They include relevant meteorological and hydrological information, but do not consider water uses in the basin
- A clear criterion to identify droughts is not universal
- Classical drought indices do not correlate well with historical drought impacts, due to the effect of storage (e.g., over year storage)
- Relevance of these indices t for Risk Analysis and Drought Management Plans to be considered.

Key issues

- Indicators and indices are sector/system specific

- Indicators should be calibrated with observed impacts, risk level, and vulnerability reducing targets
- Multiple indicators are needed

2.5.3. Risk analysis

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 and their underlying causes.

Methods

- Definition of risk: Conceptual definition of risk and compatibility with the working operational concept in each study sector and area.
- Identification and perception of the historical potential impacts of drought in the different sectors/systems based on historical data.
- Characterization of risk in the different sectors/systems. Identification of the direct consequences of drought (fair inference and attribution). This includes the application of the drought indices to establish risk level.
- Vulnerability assessment. Identify underlying causes of risk derived from inadequate management or policy options. The objective is to increase the adaptive capacity and develop policy decisions to increase adaptation options
- Action identification. Identify options to reduce risk by reducing the underlying causes (vulnerability). This aspect is fully described in the Operational component.

Expected outcome

- Drought characterization, linking drought indicators to impacts or damages
- Identification and perception of historical and potential impacts
- Definition of the affected systems and selection of the variables that characterise them in relation to drought
- Characterisation of risk (risk functions and sensitivity analysis)
- Establishment of threshold levels that trigger management actions (acceptable level of risk)
- Vulnerability analysis (diagnostic analysis of the underlying variables that result in the current drought sensitivity)

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

Definition of risk

Source: The UN International Strategy for Disaster Reduction (UNISDR) http://www.unisdr.org/

RISK = HAZARD x VULNERABILITY

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.

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 characterised 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 increases 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.

Since both hazard and vulnerability are dynamic and region/sector specific, risks must always be framed in a specific geographical or organizational context. Partners should characterize drought risks at the most possible disaggregate level and then integrate to a level adequate for establishing general conclusions for drought management plans. An example of this is a hydrological system including various interconnected reservoirs, from which urban and agricultural users are supplied. While it is clearly necessary to analyse the whole system's drought risks, much more inference potential can be gathered if intra-sectoral risks are also analysed.

Identification and perception of impacts

Some of the more common types of drought impacts are in the economic, environmental, and social sectors. Table 5 summarizes the main impacts to be considered in each sector. Similar approaches are proven to be very effective in evaluating the impacts 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 on drought damage; such is the case of groups that have contrasting economic or environmental priorities. A useful attribute to drought impact analysis is the definition of the interest group and the level of agreement within the members of the group.

Sector	Impact
ECONOMIC	Decreased production in agriculture, forestry, fisheries, hydroelectric energy, tourism, industry, and financial activities that depend on these sectors
ENVIRONMENTAL	Decrease water supply and quality of surface and groundwater water Increased soil erosion and sediment transport Decreased air quality Damage to ecosystems and wetlands, biodiversity and diseases Increased fires
SOCIAL	Damage to public health and safety, by affecting air and water quality or increased fire Increase social inequality, by affecting different socio-economic groups Tensions among public administrations and affected groups Changes in political perspectives

Table 5: Summary of the main impacts to be considered in each sector (adapted from Wilhite, 2005)

Characterization of risk

This component aims to quantify drought impacts on representative sectors. Proposed representative sectors are: rainfed agriculture, irrigation, urban water supply, environment and energy generation. For each of these sectors, the impact of each drought period should be quantified, using one or more variables. For instance, impacts 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 system various demands (e.g., drinking water, irrigation of public parks, etc.).

The methodology is the identification of the direct consequences of drought (fair inference and attribution), such as reduction in crop yield, reservoir depletion, and also the secondary consequences of drought such as land abandonment due to reduced crop yields and subsequent loss of farm income. This includes the application of the drought indices to establish correlations with the variables that represent the affected sectors, such as correlation of the Standardized Precipitation Index (SPI) with the crop yields.

The expected results are:

- Analysis of the direct correlation of drought episodes with primary variables that characterize hydrological and water supply systems, including groundwater and agricultural systems (rainfed and irrigated).
- Evaluation of the secondary consequences of the primary effects, often economic, social and environmental effects. A semi-quantitative and qualitative evaluation is expected.
- Evaluation and understanding of the reason why specific impacts occur. This will be the basis for improving adaptive capacity (reducing vulnerability).
- Identification of the levels of risk acceptable in each case and definition of the thresholds that trigger the operational actions to manage or mitigate drought.

Characterisation of risk in hydrological and water supply systems

Risk in hydrological systems is directly related with water scarcity, which differs from drought because it is related to a shortage of water availability to satisfy demands. The shortage results from an unbalance 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 infrastructure and management strategies. The result of the unbalance is demand deficit, which is of concern for water managers.

Risk analysis in hydrological systems consists on identifying demands that may not be fully satisfied with available water resources, and quantifying the estimated impacts of water shortage. It is usually anti-economical to guarantee 100% all demands in a system, and a risk level has to be adopted in the risk management plan.

The acceptable risk level is conditioned by available water resources and infrastructure 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
- Unexpected climatic events whose magnitude or duration is not included in the available time series considered when setting up the guarantees.

These factors determine also the operational rules for system management during droughts. In regulated systems, guarantee 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. Guarantees are defined depending on location of the risk management unit (i.e., up or down stream). Up-stream units need to consider also the risk of down-stream units.
The distribution of resources in a drought period among multiple demands in hydrological systems 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 optimisation 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 demands 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 many cases. They require a large investment in information, to evaluate resources, characterise 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, such as the ones listed below.

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.
- Statistical measures of variability of water inflows. They have to be derived from the distribution function that better fits historical inflows of the system, such as correlations, standard deviation, skewness, coefficient of variation, consecutive low flows, etc. This provides basic information on the risk levels that the system is supporting by assigning probability levels to a given scenario.
- Water demand / Reservoir capacity (including dams, aquifers, drinking water reservoirs, etc). 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.

The ecological requirements should also be considered and relevant indicators should be included. For surface and groundwater, the WFD requirements have to be taken into account (see Introduction).
The possibility of including decision support systems for planning of hydraulic resources should be explored in each case. For example, Aquatool, developed in the Universidad Politecnica de Valencia, Spain, (http://www.upv.es/aquatool) has been applied to real cases of planning in Spanish basins (Júcar, Segura, Tajo.) and world wide (Argentina, Brazil, Italy, etc.).
Groundwater is a strategic water supply source in Mediterranean countries, and its strategic value becomes more relevant during drought conditions. Only prolonged meteorological droughts have and effect on groundwater levels. Groundwater drought affects well-water

yield and chemical composition, and in turn impacts economic activities (i.e., decrease in crop yields) and the environment (i.e., species habitats). Critical level of groundwater can be derived from the minimum threshold levels associated with no impacts.

Characterisation of risk in agricultural 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 risk is relatively simple to analyse 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. Table 6 outlines the characteristics of subsistence and commercial farming systems.

	Subsistence farmers	Commercial farmers
Farmer's strategy of production	Stabilize food production	Maximize income
Risk	Malnutrition and migration	Debt and cessation of activity
Source of risk	Weather	Weather, markets and policies
Non-structural risk avoidance mechanisms	Virtually non existent	Insurance, credit, legislation
Inputs and farm assets	Very low	Very significant
Price of food crops	Local for primary crops and partially global for industrial crops, with some interference of governments	Global with some interference of policies
Role of cattle	Banking system, i.e. cash reserve.	Cash production

Table 6: Characteristics of subsistence and commercial farmers (adapted from Gommes, 1999)

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

1. Identification of the agricultural system(s) representative of the river basin or water catchment system. For example, subsistence farmers in dryland areas, commercial irrigated farms, etc.
2. Definition of the variables that characterise each agricultural system. For example, crop yield, irrigation water demand, etc.
3. Definition of the basic cost structures and revenues of the farms.
4. Definition of theoretical causal relationships between the agricultural variables and drought. In order to establish solid evidence of the drought risk in the agricultural sector, it is essential to provide the largest possible quantitative information to place inference confidence in the estimated correlations.
5. Statistical analysis of the correlations of drought indices with the selected variables that define the system(s). 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 into the management plans.

6. Definition of an aggregated measure of sensitivity of the agricultural system to drought based in the combination of the partial impacts. The aggregated measure may be constructed by normalizing and scaling the proxy variables with respect to some common baseline.

Table 7 shows a possible range of indicators that can be used to characterise the agricultural system (step 1 and 2 outlined above).

Category	Proxy variables
Farms representative of the geographical unit	Land holding structure Revenue sources Costs' structure Labour organization Capital Access to irrigation
Farmers and rural communities	Crop and animal distribution Crop and animal production Farm Gross Revenue (Margin) Farm census
Agricultural ecosystem services	Area occupied by extensive farming systems Area of farm land Water Nitrogen leaching

Table 7: Components of the sensitivity of agricultural systems to drought and proxy variables

Figure 16 provides a concrete methodological example for evaluating steps 1, 2 and 3 of the overall methodology outlined above.

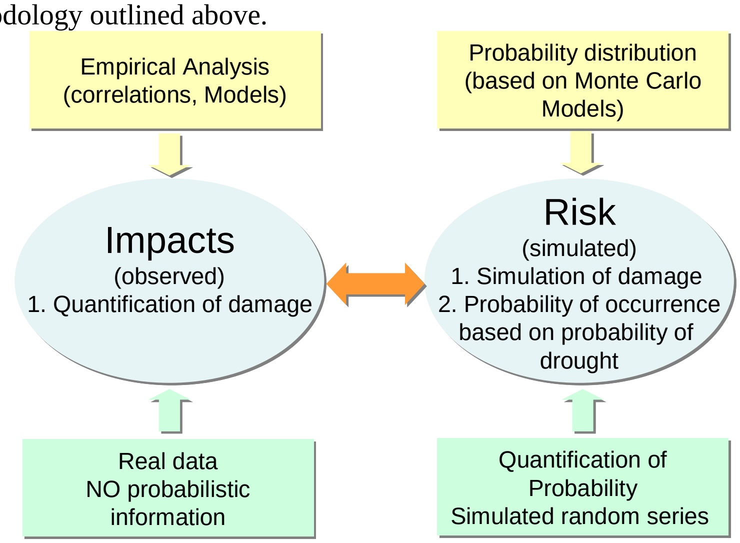


Figure 16: Technical approach to analyse risk

2.5.4. Vulnerability assessment

Objective

The objective of the vulnerability assessment is to identify underlying causes 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 form:
Vulnerability derived from the direct exposure to drought.
Vulnerability derived from 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 resiliency; in general marginal and poor farming systems suffer the largest consequences of drought.

Expected outcome

The expected outcome is to identify the aspects of each system that makes 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 (Ribot et al., 1996).

Socio-economic vulnerability

This component analyses the underlying social causes of vulnerability not directly related to the sensitivity of the system to drought. An example of the components of socio-economic vulnerability and the proxy variables that can be used to characterise it is provided in Table 8. A final indicator for each category of exposure may be computed as the weighted average of all the proxy variables within the category.

Category	Proxy variables
Economic capacity	GDP per capita
Human and civic resources	% Population in the workforce % Population with a graduate degree
Agricultural innovation and information dissemination	Public expenditure in agricultural research and extension / population Technological gap for cereal production
Renewable natural capital	Population density % Land unmanaged

Table 8: Components of socio-economic vulnerability and proxy variables that can be used to characterise the vulnerable groups

An index to evaluate vulnerability

The sequential steps to be taken for the quantification of overall vulnerability of a system are:

- Define an aggregated index derived form the analysis of the vulnerability directly related to drought exposure.
- Define an aggregated index of socio-economic vulnerability based on the analysis of proxy variables.

The index may be constructed by normalizing and scaling the proxy variables with respect to some common baseline.

2.6. Operational component

2.6.1. Overview

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

The operational component includes following aspects:

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

Monitoring and preparedness planning is the essential first step for moving from crisis to risk management in response to drought, and can be viewed as the permanent measures of a drought management plan. The management actions related to agriculture and water supply systems are presented in two different chapters but with a common conceptual framework based on the use of drought indicators for evaluating the levels of drought risk (pre-alert, alert, and emergency), that allow establishing linkages between science and policy.

2.6.2. Preparedness and early warning

Preparedness and early warning is the key for later operational management and determines the success of the overall drought management plan:

- Establish the drought master plan
- Reduce social vulnerability
- Define the actions to be taken upon drought
- Identify alert mechanisms
- Establish the links between drought and water and development policies

Scientific advancements 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.

2.6.3. Establishing priorities

The management actions are evaluated as to the possibility to be applied to other regions.

- First priority: Ensure 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.

2.6.4. Defining the thresholds

Key issue: Drought declaration

The formal declaration of drought is an issue both controversial and important.

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 management actions.

The management actions related to agriculture and water supply systems are presented together with a common conceptual framework based on the use of drought indicators for evaluating the levels of drought risk (pre-alert, alert, and emergency), that allow establishing linkages between science and policy. The rationale is that the actions relevant to all sector are based in common institutional organization, legal framework, and are implemented by a unique decision making structure (defined in the organizational component of the Guidelines).

Figures 17 and 18 synthesise the thresholds levels, the objectives of the actions to be taken and the action groups in each threshold category.

Pre-alert

The pre-alert scenario is declared when monitoring shows the initial stage of drought development, which corresponds to moderate risk (i.e. greater than 10%) of consuming all water stored in the system and not being able to meet water demands. 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 kinds of measures that are taken in the pre-alert situation are generally of indirect nature, are implemented voluntarily by stakeholders and are usually of low cost. The goal is to prepare the organism and the stakeholders for future actions. Regarding the Basin Authority, 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 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 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 (i.e. greater than 30%) having water deficits in the time horizon. The management objective in the alert situation is to overcome the drought avoiding the emergency situation by enacting water conservation policies and mobilizing 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 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 are 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 user rights and priorities under normal conditions are overruled, since water has to be allocated to higher priority uses.

Emergency

The emergency scenario is declared when drought indicators show that impacts have occurred and supply is not guaranteed if drought persists. The management objective is to mitigate impacts and minimize damage. The priority is satisfying the minimum requirements for drinking water and crops. 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.

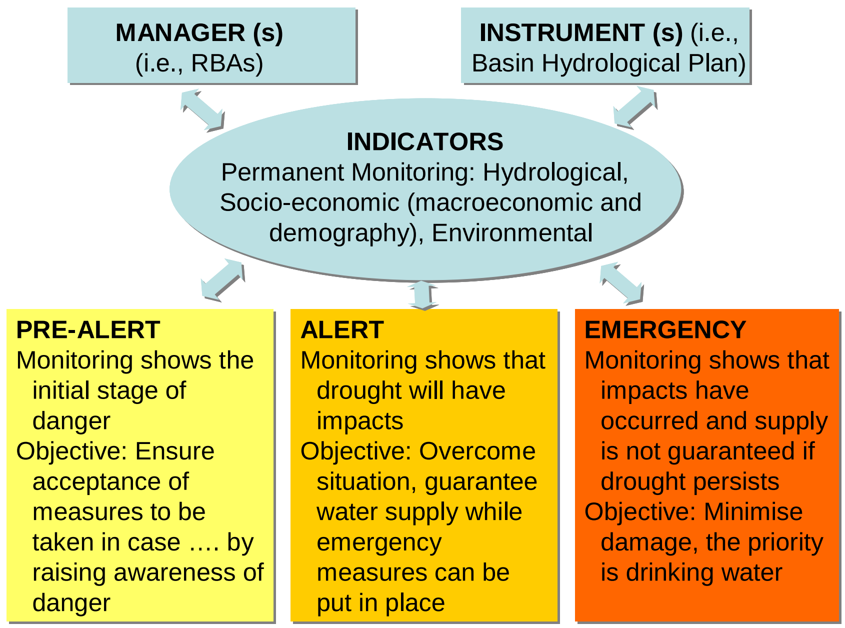


Figure 17: Threshold levels and objectives of the actions to be taken

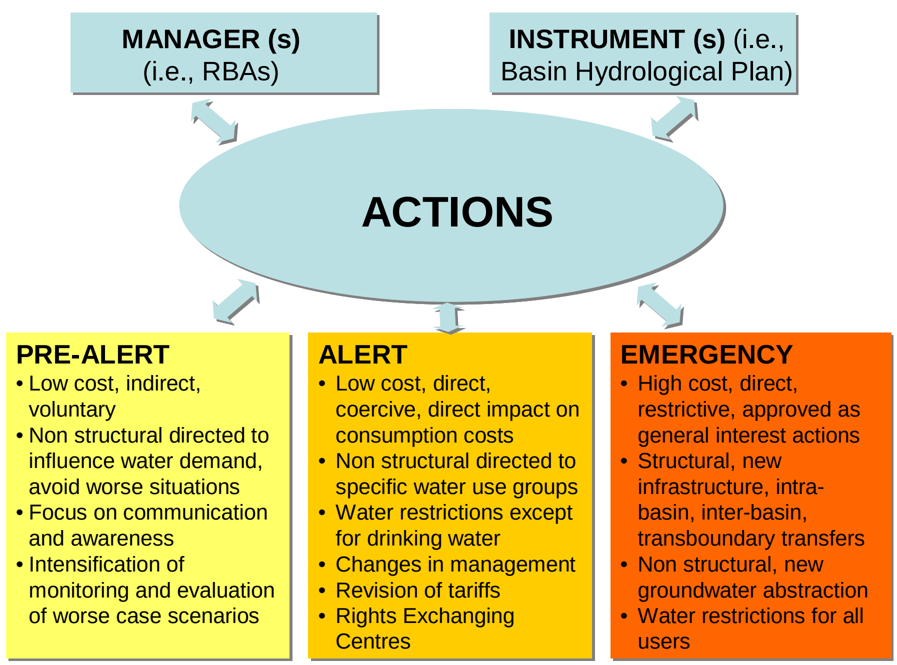


Figure 18: Threshold levels and groups of actions to be taken

2.6.5. *Evaluating the process to implement the actions*

The possibility to implement the actions in each case is determined by the legislative and institutional framework. An example is given in Figure 19.

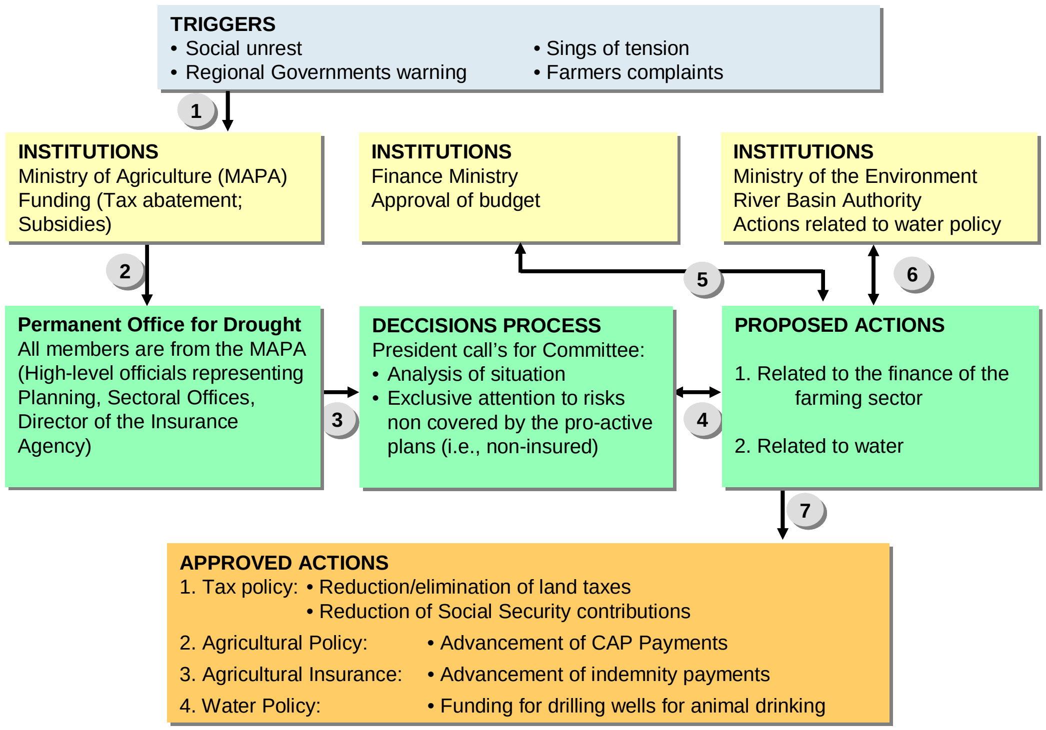


Figure 19: Example of action implementation process (source: Spain)

2.6.6. *Defining the actions*

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

Description

- A description of an historical example and evaluation of its success
- Organizational unit responsible for the action
- Timeframe of implementation
- Comments on the application to other areas

Ranking

- Objective of the operational action: To minimize impacts of drought and water scarcity while maintaining social and ecological services of water.
- Consideration of effectiveness to minimize the risk of impacts, cost, and 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 valuations criteria that include the full range of stakeholders defined in the organizational component.

Table 9 gives and example for ranking and valuating the actions.

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

Table 9: Valuation of attributes of each action

Proactive and reactive measures

In order to incorporate the actions to drought management plans it may be useful to determine the public or private, as well as the proactive or reactive character of the measures (see Table 10 as an example).

	Public(1)	Private(2)	Mixed
Proactive(3)	Insurance plan for agriculture	Education programmes by NGOs	Education programmes under private initiatives with Government funds
Reactive(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

Table 10: Example of proactive and reactive private and public measures to reduce drought risk

(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 an awareness or 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 on the actor's rational self-interest.
(3) Proactive. Measures established before impacts of drought are observed (anticipatory) to lower the risk of damage. Addresses preparedness and risk reduction
(4) Reactive. Measures that take place after impacts of drought have been observed. Addresses crisis management

Examples of drought management and preparedness actions

Table 11 outlines examples of drought management and preparedness actions as an example to start the dialogue with stakeholders.

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 programs		A	I	
	Short-term actions				
Demand reduction	Public information campaign for water saving	U	A	I	R
	Restriction in some urban water uses (i.e. 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 programs, 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

Table 11: Long and short term drought mitigation measures (Rossi, 2000 modified)

2.7. Public review component

Public review has to play an important role along the process of developing a plan 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 of the plan.

In all cases public revision is complex, but in most cases includes two aspects: 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 allow the participation and discussions among all stakeholder groups.

2.8. Examples of the application: Spain

2.8.1. The planning framework

Societal responses to drought

Drought can have serious effects on the economy and the environment of Spain and on the population's well being. The major drought of the mid 1990s affected over 6 million people, almost ten times more than the number of people affected by floods in Spain during the last fifty years. The economic damage caused by drought in Spain during the last twenty years is about five times more than in the entire United States. Drought events affect water supplies for irrigation, urban, and industrial use, ecosystem's health, and give rise to conflicts among users that limit coherent integrated water resource management. Ecosystems are deteriorating and drought is the main issue. Deteriorating water quality parameters may not be acceptable for human consumption during drought. The reduction of wetland area (over 1200 km² in the 1970s to less than 800 km² in 2000, excluding the Guadalquivir marshlands) has been in part related to recurrent drought episodes and surface water scarcity, and amplified by the excessive groundwater pumping to compensate for these problems.

Groundwater resources play a vital role in meeting water demands, not only with regards to quality and quantity, but also in space and time, and are of vital importance for alleviating the effects of drought. Direct use of groundwater in Spain is currently estimated at 5 km³/year, mainly for irrigation use (80%), but the water quality is easily deteriorated due to point-source pollution or diffuse pollution caused by agricultural and livestock activities.

The implementation of the European WFD gives Spain the opportunity to develop integrated drought management plans that incorporate the extensive national experience in hydrological management with the new environmental challenges. Historically, the urban, cultural, and agricultural development in Spain has demonstrated a profound knowledge of adaptation strategies to drought, water scarcity, and precipitation variability.

Drought, water scarcity and aridity are overlapping issues

Water resources are limited, scarce, and difficult to predict year on year. Regulated water resources in Spain account for 40% of total natural resources, compared with 8% worldwide, since the potential use of surface water under the natural regime is only 7%. Groundwater use is intensive in many areas of the country contributing to an additional 10% of the total available resources. With limited and scarce water resources and demand rising due to demographic shifts, economic development and lifestyle changes, water management problems are significant even without drought events. Water use is mainly for agriculture (over 68% of water demand), but other economic and social water demands are rapidly increasing, such as tourism (current urban demand is 13%) and ecosystem services.

Purpose and process

The Tagus basin is currently developing a drought management Plan, which is integrated into the long-term strategies for water management. The elaboration of the Plan is the result of a complex process in which user participation is encouraged and stimulated. Once the Plan is drafted, it is submitted to public scrutiny, and concerned individuals and social or political groups can make allegations that are discussed and negotiated in the Water Council, where a majority vote is required for acceptance. If the drafted plan obtains a favourable vote, it is approved by Royal Decree, and is legally binding to all stakeholders.

The disagreements among stakeholders usually concern the timing of measures to be applied during drought. Users that are going to be benefited by measures, because their demands will be protected due to the high priority of urban supply, tend to encourage early action, even at the risk of incurring frequently in false alerts and unnecessary restrictions. Users, whose demands are going to be restricted, because of lower priorities of irrigation or power production, tend to support the delay of the application of exceptional measures, even at the price of depleting the reserves completely.

To avoid conflict among stakeholders and ensure the effective application of measures, it is important that the rationale behind the measures proposed in the plan can be understood by all affected bodies, and therefore, special emphasis has been placed on developing a methodology to establish an objective link between quantitative drought indicators and concrete measures. The methodology involves a comprehensive analysis of alternative policies and an objective procedure to plan the ordered implementation of management actions based on quantitative drought indicators.

2.8.2. Organizational component

The case study (Tagus river basin) and the national context:

The Tagus river basin is the geographical unit selected as the case study for the application of the Guidelines (Table 12 and Figure 20). The Tagus basin is located in the centre of the Iberian peninsula, with a contributing area of 83,678 km², of which 55,870 km² are located in Spain and the rest in Portugal. The amount of water that has to reach the river in Portugal is determined by the international Albufeira regulation. The Tagus basin also supplies water to the Segura basin, a water scarce basin in the eastern Mediterranean area of Spain.

Figure 20: Hydrological basins in Spain (see Table 12 for names).

	Total Freshwater resources (km³)	Available resour-ces (km³)(a)	Reser-voir capacity (km³)	Regula-ted water (%)(b)	Demand (% of available resour-ces)	Irrigation demand (% of total demand)	Popu-lation (million)	Total resources per capita (m³/hab)
Norte (1)	44.2	6.8	4.4	15	37	42	6.7	6,542
Duero (2)	13.7	8.1	7.7	60	47	93	2.2	6,071
Tajo (3)	10.9	7.1	11.1	65	57	46	6.1	1,784
Guadiana (4)	5.5	3.0	9.6	54	85	90	1.7	3,298
Guadal-quivir (5)	8.6	3.6	8.9	42	104	84	4.9	1,755
Sur (6)	2.4	0.54	1.3	21	268	79	2.1	1,135
Segura (7)	0.8	0.7	1.2	90	253	89	1.4	590
Júcar (8)	3.4	2.0	3.3	58	149	77	4.2	819
Ebro (9)	18.0	13.0	7.7	72	80	61	2.8	6,509
Catalonia (10)	2.8	1.1	0.8	40	122	27	6.2	451
Baleares (11)	0.7	0.3		45	96	66	0.8	785
Canary Is. (12)	0.4	0.4		102	102	62	1.7	241
SPAIN	111.2	46.6	56.1	42	76	68	40.1	2,728

(a) Surface and groundwater. Overall groundwater contribution is under 20 percent of total.
(b) Regulated water: rate of available resources from total natural resources.

Table 12: Total freshwater resources, available resources, demands, and water reliability in the hydrological basins of Spain.

Legal and institutional framework

The analysis of drought risks is incorporated in the Law of the National Hydrological Plan, within the realm of agricultural and hydrological droughts, although there is room for improvement on the risk analysis within the contingency plans of the Hydrological Basins. Future adaptation options of the Basin Institutional framework to the requirements of planning based on risks analysis and strategies design, rather than work based plans, remains a challenge for the future.

There are two main legal sources of the Spanish water codes and statutes derived from the Spanish Constitution (1978) and from the European Union WFD (2000). These two legal bodies are on top of the hierarchy of laws and statutes pertained to water and droughts. Three instrumental laws are identified as the main precursors of drought preparedness and planning: The Water Law (2001), the Law of the National Hydrological Plan (2001) and the Agricultural Insurance Law (1978).

The administrative body that is responsible for providing public service regarding water management in the basin is the Basin Authority, with competence on inland water and groundwater. The Basin Authority is an autonomous public organization subordinate to the Ministry of the Environment. The Ministry of the Environment also hosts the National Drought Observatory that provides updated general information.

Stakeholders and priorities

Table 13 summarises the stakeholder groups that may compete for water during periods of drought and water scarcity.

Stakeholder	Variable of interest	Preference and compromise
Farmers	Water to irrigation	More water May be willing to accept lower abstraction permits in exchange for lower price (or vice versa, may be ready to pay higher prices to obtain more water)
	Price of water for irrigation	Lower price Subsidies for switching to less water-demanding crops
	Dam and reservoir capacity	More capacity (decrease vulnerability to drought)
Environmentalists	Residual water	Well above minimum flow requirement
	Dams and reservoirs	No additional investment to protect biodiversity Sustain ecological flow
Urban and Rural dwellers	Secure access to safe water	Closer safe water sources Guaranteed minimum water quantity Participatory water planning
Urban water supply companies	Dams and reservoirs	Increase storage capacity Infrastructure
Basin Authority	Dams and reservoirs	Integrated resource management Evaluate storage capacity First priority is urban water supply Other uses and services of water may be negotiated
	Ecological water	Guarantee ecological services and flow requirements

Table 13: Stakeholders in the Tagus basin

2.8.3. Methodological component

Meteorological and hydrological drought

Drought characterization in highly regulated systems is complex and calls for multiple indicators. Time series of aggregated precipitation in Spain define meteorological drought episodes. The SPI and other indices have been used with important limitations when used in isolation, especially over short time periods. The methodology is based on a system of drought indicators and a list of pre-specified drought mitigation actions for every system. Executive drought indicators are used to declare drought scenarios, which are associated to the implementation of managing actions.
Data show a possible intensification of drought conditions in recent years, during the decades of 1980’s and 1990’s. However, since droughts were also important during the 1940’s and 1950’s, the question arises of whether drought has a multi-annual cycle of wet and dry conditions with a period of about 40 years or whether recent droughts are a consequence of man-induced climate change.

Hydrological risk analysis

The basis of any drought management plan is a robust system of indicators that can identify and diagnose anomalies in water availability and can provide the basis for early detection of drought episodes. A comprehensive study of hydro-meteorological time series and drought indices in the basin led to the definition of a drought indicators system. The system is in continuous revision, taking into consideration the availability of new information and the progress in knowledge of the hydrologic behaviour of the basin.
Variables used as early warning levels to predict droughts are grouped in two categories: informative and executive. Informative variables provide information on the development of the drought, and are used as a monitoring tool. Executive variables are objective indicators that are used to trigger specific actions in an operational context. Two types of analysis are performed: Probabilistic and deterministic.

A. Probabilistic analysis

The objective of the analysis is to define the thresholds for the declaration of the pre-alert, alert and emergency scenarios. Since future reservoir inflows are uncertain, these thresholds should be formulated in probabilistic terms. Thresholds are defined as the available storage in the system, S, that is required to satisfy a fraction, f, of the demand in a time horizon, h, with a given probability, p. Values of f, h and p are model parameters that should be fixed though discussion with stakeholders. They depend on several factors: the type of the demand in the system (urban, irrigation, hydropower, etc.), the reliability of the current water supply system, the alternative management strategies that can be applied during droughts, the vulnerability of the demand to deficits of a certain magnitude, etc.

B. Deterministic analysis

From the perspective of user involvement in the process, the presentation of probabilistic results is always faced with reluctance. Users are not willing to accept restrictions based on a probability of failure, especially if that probability is not close to one. Implementation of measures usually takes time, and if the activation of the drought situation is delayed until there is almost a certainty of deficit, it is very difficult to avoid important impacts. For that reason, a simplified version of the procedure was developed for the purpose of dissemination and negotiation with users. Rather than using a probability distribution of required storage volumes, the decisions are based on a set of droughts, which are selected as representative of droughts of different severity occurred in the past in the system. The methodology is structured in three phases: (1) Definition of characteristic droughts; (2) Definition of drought thresholds; and (3) Validation of the model.

The cumulative distribution of annual flows in the system can be fitted to a normal probability distribution. The characteristic drought was chosen as the minimum value in historic record, 117.91 Mm^3/yr, which corresponds to a probability of excess in the normal fit of 95%. According to this, three scenarios are defined to link risk evaluation with operational aspects:

- Pre-alert scenario: 90% of the urban water supply demand and 80% of the irrigation demand during at least 1 year.
- Alert scenario: 80% of the urban water supply demand and 60% of the irrigation demand during at least 1 year.
- Emergency: 70% of the urban water supply demand and 40% of the irrigation demand during at least 1 year.

Model validation was performed by simulating the system with and without the implementation of drought management rules. There are three severe drought episodes in the historic record in which the reservoirs of the system are completely empty, and there is a deficit of 100% of the demand during several months. This situation is catastrophic, and should be avoided by defining drought management rules that conserve water in the system. As a first approximation, these rules have been simulated as reductions of the demand supplied by the system in every drought scenario.

2.8.4. Operational component

The operational effectiveness of the drought management plan is greatly enhanced if the selected measures for every system are grouped. In the Tagus Basin Plan, drought management strategies are grouped in three scenarios, corresponding to increasing levels of severity: Pre-alert, alert, and emergency scenarios. The basin drought policy is summarized as a list of possible actions to be taken in case of drought. The catalogue of possible actions is restricted by the legal competences that are attributed to the organism, but the resulting list includes a great number of actions of very diverse nature, like the examples presented in the following categories:

- Internal operation. Within the Basin Authority, most frequent measures include intensification of monitoring, prevention of leaks, or revision of rules for the operation of infrastructure.
- Water uses. Demand management measures include: information dissemination and user involvement, promotion or enforcement of water savings, prohibition of certain uses, temporary exemption of environmental obligations, etc.
- Water resources. Drought measures focus on conservation and protection of stored resources, activation of additional resources or monitorization of indicators of water quality.
- Institutional. The President of the Basin Authority may appoint committees or task forces to address specific issues, usually in conjunction with affected users, or enhance cooperation with other organizations or stakeholders.
- Legal. There are a number of legislative measures that can be adopted, ranging from the official declaration of emergency due to drought, to a long list of possible palliative measures with different objectives: subsidy, restrictions, emergency works, etc.

The operational implementation of the plan requires a connection between the system of drought indicators and selected measures. To avoid untimely negotiations, the drought plan contemplates the activation of the set of measures associated to a drought scenario when a given drought indicator reaches a predefined level. The final goal is to achieve a balance between the frequency of declaration of drought scenarios and the effectiveness of the application of the measures. If drought scenarios are declared too early, users are frequently exposed to unnecessary restrictions. If the declaration of drought scenarios is delayed, it may be too late for the measures to be effective. Computer modelling is an essential tool to analyze the problem and to find a consensus among users by testing different options.

Actions

- Pre-alert scenario: no specific demand reductions. Only awareness measures are contemplated.
- Alert scenario: reduction of 15% of the demand, which corresponds to a reduction of 35% in supply to irrigation and no reduction in supply to urban demand. For example, irrigation can be supplied using waters from a nearby supply, although farmers usually disagree with this option, since it may imply lower water quality and an increase in the pumping costs.
- Emergency scenario: reduction of 50% of the demand, which corresponds to no supply to irrigation and 15% reduction in supply to urban demand. Urban demand can use alternative water supplies, but this possibility depends on the situation of their own water supply systems.

The results of these actions have been simulated with the probabilistic and deterministic risk analysis methods described above. The proposed rules can reduce maximum deficit in the system to 50% of total demand, but at the cost of more frequent restrictions. There is always this trade-off between water conservation measures and drought risk. Early response to drought risk implies producing restrictions that could have been avoided, but it can also avoid important deficits of catastrophic consequences. The results of the simulation can be analyzed to assess the frequency of drought declarations.

2.9. Drought planning and the Water Framework Directive

Developing comprehensive, long-term drought preparedness policies and action plans may significantly reduce the risks associated to extreme weather events.
Article 13 of the WFD indicates that 'River basin management plans (RBMP) may be supplemented by the production of more detailed programmes and management plans for sub-basin, sector, issue or water type, to deal with particular aspect of water management'.
Therefore Drought Management plans (DMP) or part of them could be considered as supplementary plans to the RBMP. Indeed drought planning can be developed at different levels:

- <u>National level</u>
  At national level focus must be put in policy, legal and institutional aspects, as well as in funding aspects to mitigate extreme drought effects. These are strategic measures.
  General long-term measures are the focus of national level measures as well as transboundary measures, but not exclusively; these types of measures must also be developed at RBMP level. In connection with river basin or local levels, national level measures must determine drought on-set conditions through a network of

global indices and indicators at the national or regional level global basin indices/indicators network, which for instance can activate drought decrees for emergency measures with legal constraints or specific budget application.

- River basin level
  Drought Management Plans at river basin level are contingency complementary management plans to River Basin Management Plans. DMPs are mainly targeted to identify and schedule on-set activation tactical measures to delay and mitigate drought effects. Therefore, measures involved are mainly water demand or water conservation measures and, with the progressive application of WFD schedule, measures to achieve and comply with good environmental status.
  In this sense, RBMP have to include a summary of the programmes of measures in order to achieve the environmental objectives (article 4 of WFD) and may be supplemented by the production of more detailed programmes and management plans (e.g. DMPs) for issues dealing with particular aspects of water management.
  Regarding exceptions, "prolonged droughts" are introduced in the WFD as "force majeure" events. Therefore, clear definitions of what is understood by "prolonged droughts" will have to be established. The conditions under which exceptional circumstances are or could be considered have to be stated through the adoption of the appropriate indicators. Contingency drought plans must face these issues.
- Local level
  At local level, tactical and emergency measures to meet and guarantee urban water supply as well as awareness measures are the main issues.

2.10. Drought planning: other examples

2.10.1. Singular non conventional management measures for water conservation, Cyprus

Water scarcity is a reality in Cyprus. Presently, water demand for various uses exceeds the amount of water available, while in recent years, the problem has been exacerbated due to the observed prolonged periods of reduced precipitations.
In order to achieve minor water scarcity deficit, the Government of Cyprus has adopted novel actions for water conservation using second quality water or "grey waters": establishment of subsidies for saving good quality domestic water through the connexion of private boreholes to toilet tanks or for the installation of grey water recycling systems in houses, schools, for watering gardens and toilet flushing, etc. Lightly polluted or "grey water" from baths, showers, hand or wash-basins and washing machines is kept separated from heavily polluted or "black water" from WC and kitchens. As a result, it is relatively easy to intercept each type of wastewater at household level for subsequent treatment and reuse. With this scheme, Cypriots have achieved a drinking water conservation of 30 % to 65 %.

2.10.2. Drainage water reuse as a mean of fighting water scarcity, Egypt

To properly assess the future status of water resources in Egypt, the national water resources plan is considered as a model example document towards development of the integrated water resources management. The document focuses on the physical improvements necessary to satisfy the supply-demand imbalance. The totality in the approach to water resources/agricultural/urban water management is significantly expressed throughout the plan. The national plan emphasizes the coordination between ministries, stakeholders, NGOs and civil societies to ensure the successful implementation and sustainability for the integrated management of the water resources. Institutional reform, financial and privatization, planning and cooperation, and gender issues were also considered in the plan.

The Ministry of Water Resources and Irrigation of Egypt was entrusted to carry out a long-term monitoring program to give answers to decision and policy makers about the quantity and quality of drainage water and its locations. A monitoring network of 90 measuring locations on the main drains in the Nile Delta and Fayoum was established in the early 1980's, providing daily measurements of drainage flow and bi-weekly salinity and other chemical components. Since then, the network has been continuously maintained and upgraded to furnish reliable measurements. The current monitoring network in the Nile Delta and Fayoum consists of 140 sites for monitoring the quantity and quality of drainage water in the main and branch drains with a monthly frequency. The number of parameters is increased to 31 parameters, taking into consideration toxicological, microbiological, oxygen budget related and extended ions, metals and trace elements as well as the classic parameters.

The field measurements and laboratory analysis are regularly stored in an interactive database, continuously maintained and finally linked with a Geographical Information System (GIS). The monitoring results are routinely published in yearbooks and disseminated to all concerned decision makers. Historical data is now available about drainage water quantity and quality in the Nile Delta for the last 15 years. Many important decisions regarding the existing and future plans of drainage water reuse were taken on the basis of this information. The monitoring program clearly reveals that the drainage water quantity changes with time, depending on water use policies and the management of the main supply system. The variations occur from month to month, season to season, and year to year. The average drainage water discharged annually to the sea is 12.5 bcm. The measured drain discharges to the sea are not entirely excess irrigation water. They include brackish groundwater, sea water and M&I wastewater discharges.

The results of monitoring and experimental areas were used to develop guidelines for using drainage water in irrigation on environmentally sound basis. The guidelines enable the user to rate salinity hazard factors and suggest irrigation and crop management practices to overcome hazards, forming a decision support system for use of drainage water irrigation for sustainable crop production. The guidelines are intended for use on currently cultivated lands as well as on new land being brought into production by reclamation. They are meant to be applied to a specific crop or to a crop rotation that is to be irrigated with a water of known quality under particular soil salinity and hydrologic conditions. The guidelines contain three matrices organized in categories of crops: salt tolerant, moderately salt tolerant, and salt sensitive crops. The matrices are designed to identify and compare the relative potential hazard of crop yield reduction and soil salinization when using various types of irrigation water.

Three major effects are considered in the organization of each matrix: the direct impact of irrigation water quality on crop yield via irrigation water salinity and sodicity hazard; irrigation water management related to consumptive use and leaching requirement of the crop; and soil quality. This last factor rates the potential of the soil to remain a suitable medium for plant growth related to soil salinity and sodicity. The guidelines also include criteria for environmental protection and public health preservation. Additionally, they rate the degree of socio-economic vulnerability of the farmers involved in the use of drainage water, and list institutional measures indicated to mitigate the risks.

Faced with the future challenges, the Ministry of Water Resources and Irrigation started an integrated management approach that combines all available resources (freshwater canals, drainage water reuse and groundwater) to meet the water demands of different users. The approach requires full coordination between government institutions at all levels and active participation of water users in planning, managing and operating irrigation and drainage systems. The main pillars of the vision are Making the best agricultural, social and environmental use of the available water resources by means of irrigation improvement and changing crop patterns, Applying Integrated Water Resources Management approach through developing governmental and non-governmental Institutions as well as enforcement of laws and legislations, Allocating different conventional and non-conventional water resources, Supporting and effectuating the private sector role and Countering pollution as well as preserving water resources. This could be accomplished through cooperation with various stakeholders and institutional reform by means of merging different sectors as well as purging incompetent ones to cope with the potential changes.

2.10.3. Water allocation during drought, France

A common way to face water allocation during drought is the French model. The French Water Act of 1992 seeks to guarantee a balanced management of water resources, allowing prefects to share these resources in case of crisis. Several tools are used to limit the impact of crisis situations when they occur: in the event of a proven crisis, i.e. as soon as the low flow-rate limits are exceeded, various measures may be taken to temporarily limit or suspend uses of water.

Framework decrees have been drawn up for watersheds, enabling the rules and thresholds for triggering restriction measures to be defined in advance. This approach greatly facilitates the exercising of regulations during crisis periods. It also makes possible to have greater transparency and better cooperation.

The document drawn up by the prefects indicates the warning levels (which may be gradual) and the measures to take when they are passed : uses to be suspended or scaled down, priority uses to be maintained – a definition of the priority of uses should ideally be drafted. The implementation of these measures if thresholds are passed is stipulated in a decree. Several incompressible needs have been identified and will need to be guaranteed for civil security, public health and national defence: regulated nuclear facilities, hospitals, fire-fighting facilities, etc.

The measures taken by the prefect must be appropriate. They must be sufficient in light of the severity of the situation and be in proportion. The prefects are also setting up contingency management offices with a view to organizing cooperation between users. They may bring together the various categories of users directly concerned as well as the fishing federations, nature protection associations and local water commissions when relevant.

Cooperation is the watchword for any water management system. Indeed, the law hallows it in the process of drawing up “Schéma Directeurs d’Aménagement et de Gestion de l’eau” (SDAGE), bringing together the water field players for development phases and monitoring.

The public authorities assess what measures need to be taken to combat drought in light of local circumstances (weakness of flow-rates for tables and watercourses, scale of withdrawals on the resource). Drinking water supplies remain a priority use, but it is also essential to protect and reconcile economic uses of water with efforts to safeguard aquatic environments.

Measures to limit uses of water may concern: the use of water for agricultural needs, the use of water for washing private vehicles or filling private swimming pools, the watering of public and private garden areas, the filling of man-made lakes, etc.

As water is a common resource, each person is responsible for preserving it. If they fail to comply with the restriction measures defined in the prefectoral decrees, they may be fined up to 1500 euros or even 3000 euros for repeating offenders.

2.10.4. Drought mitigation measures, Palestine

Background

In the Middle East in general and in Palestine in particular, integrated water resources management is hindered by the complex hydro-political situation, which is characterized by natural water scarcity, shared nature of water resources, conflicting demands, and intensive development and use of resources. The foremost significant uncertainty is the one related to climate change in general and to drought in particular.

Palestine enjoys typical Mediterranean climate conditions. It has two distinctive seasons; a wet winter, which lasts 5 months (November-March) and a dry summer, which nearly lasts for seven months (May-October). Rabi (1999) demonstrated that the number of rainy days is limited and rarely exceeds 60 days a year. Rainfall depth has a non-uniform distribution and exhibits high spatial and temporal variability.

Currently, 31% of the Palestinian communities are not connected to water networks. In general, local springs and rainfall collection cisterns are the major sources of water supply for domestic and agricultural use in many Palestinian communities. Therefore, the livelihood of these communities is always threatened since these sources are directly affected by rainfall and drought incidence. Rainwater harvesting supplies approximately 6.6 mcm per year. In most cases, cisterns collect water from rooftops during the rainy season, which is then stored in subsurface containers, usually ranging in size from 60-100 cubic meters. A large percentage of water collected in cisterns is used for domestic purposes. In addition, there are 297 natural springs in the West Bank which provide approximately 60 mcm per year, the majority of which comes from 114 major springs. However, it is estimated that there are actually more than 400 small and large springs throughout the West Bank. Given that recharge levels of the water table are dependent on rainfall quantities, the yield from springs varies across the years. In terms of usage, the majority of springs meet agricultural needs. However, it is worth noting that springs, particularly given the severity of the current water situation, often serve a dual purpose. (PHG, 2005)

The Palestinian Hydrology Group-PHG- has implemented in cooperation with the Palestinian Ministry of Agriculture and ACDI/VOCA, a 1.5 year Drought Preparedness and Mitigation Program in the north of the West Bank. The main goal was to support food security and economic development of poor and risk communities as a result of drought. The objectives of the program were to alleviate existing and future droughts problems through the build up of water resources; increase fresh water supply through rainwater harvesting and conveyance; develop and strengthen the agricultural sector in the local community; raise community awareness and capacity to respond to drought situations; and demonstrate practical cooperation with MoA and assist to build capacity and responsiveness to drought situation.

In total 10 communities were targeted and 8500 inhabitants benefited from the program activities. The target areas make up the food basket of Palestine, where agriculture is the main source of income and the drought season is hard due to the poor water resources infrastructure; springs are neglected, groundwater wells have old equipment and low efficiencies, water network losses are high, storage systems are absent, and soil canals are needed. In addition, public awareness about water resources is low.

The following activities were implemented in order to meet the objectives of the program:

- Construction of 17,071 meters of soil canals
- Rehabilitation of 3 groundwater wells, increasing well discharge by 65 m3/hr
- Rehabilitation of 3 springs, increasing spring discharge by 83 m3/hr
- Construction of 81 water harvesting pools, making available 33,100 m3 of water
- Construction of 46 water harvesting cisterns, making available 3,216 m3 of water
- Construction of 331.6 m2 of retaining walls

- Production of 1500 copies of posters on water harvesting, kids' story written by students on water resources protection and management, and 200 copies of a brochure on mitigation of drought.
- Conduct training for farmers, students and women in water resources management, water resources protection, water conservation, water harvesting, irrigation techniques, cost recovery, financial management, environmental campaigns, and computer skills.

This program has assisted in solving the water shortage problem and in providing additional water resources for domestic and agricultural use, making the area better equipped to deal with future drought conditions. In addition, it has increased the land area – an additional 244 dunums- and encouraged land reclamation, use of green houses and improved irrigation techniques.

2.10.5. Strategy of soil and water conservation, Tunisia

A major critical problem of agriculture in much of Tunisia is the recurring deficiency of soil moisture for crops and range production. The central farming regions (200-400 mm) and the intermountain plains (400-550mm) in the north-western part of country are particularly affected. Because of non-uniformity of precipitation patterns, many sub-humid region areas (400-550 mm) are also influenced by moisture shortage during certain periods in the growing season.

The enormity of the problem is particularly evident in the annual variation of cereal yields. The total national production fluctuates commonly in a ratio of 1 to 5 depending on the amount and timing of rainfall. The soil moisture during the planting season affects also the hectares used for cereals.

Water resources Problems:

There is an estimate that about 29 billion m^3 of the rainfall is lost by evaporation and transpiration and 0,5 billion of m^3 lost to the sea and to salty lakes. This water could be retained to improve the over-exploited water table. Furthermore some 10.000 hectares of arable land are sterilised annually in these reservoirs. Consequently, the dams lose this same volume of their storage capacity.

Strategy of Soil and Water Conservation:

A long-term strategy stressing the necessity to conserve the national soil resources and to protect the existing infrastructure was set up. A national programme to invest in soil and water conservation was established, and an estimated budget of almost 500 million dinars was used to cover the cost of all needed interventions from 1991 to the year 2002. The introduction of new farming policies based on the use of technology and adequate water harvesting practices are adopted.

This national wide project gave the opportunity to manage one million hectares and to maintain and rehabilitate 440000 ha in watersheds and cereal production regions. It has permit also to construct 580 mountain lakes (small dams with an average of capacity of 100000 m^3), 2000 small check dams to trap sediments and 2000 diversion dams for water harvesting.

After the evaluation and the success of this program, a new national plan was established for the period 2002-2011. An estimated budget of 780 million dinars was proposed to manage and maintain 1,5 million hectares in watersheds and to construct 1000 small dams, 3000 structures to recharge aquifers, 1500 diversion structures for water harvesting, 5500 protective structures for water ways and the management of 15000 ha by traditional techniques of soil and water conservation. The objectives of soil and water conservation plan are:

1- To reduce the loss arable land estimated to 10.000 ha/year.
2- To maintain soil fertility in order to avoid the decrease in soil productivity.
3- To retain the 500 million cubic meters of run-off water (which are actually lost in the sea and salty lakes), by carrying out water and soil conservation works.
4- To recover arable land by establishing structures (jessours) in the south of Tunisia.
5- To improve the life span of dams, which are threatened by sedimentation at the rate of 25.8 million cubic meter/year.
6- To reduce damages caused in valleys and plains by floods.
7- To implement a new farming policy, which aims at utilizing anti erosion works in order to increase production.
8- To create job opportunities and to improve revenues of rural population in the marginal areas.

The water harvesting interventions, as planned for in the management plan have covered different regions and proposed to reach an ambitious objective, particularity due to the fact that the anti-erosive interventions call not only for mechanical and physical measures such as (bank construction, waterway lying, drop structures, farm ponds...) but also agricultural developing interventions (fruit tree planting, forage crop, range management, change in crop production) with an effective farmer's participation. Water and soil conservation division in collaboration with other technical institutions is aiming at increasing production to reach food self sufficiency, improving revenues and standards of living of the rural population, creating job opportunities and reducing the rural urban migration.

An Integrated water and Conservation Approach:

In order to reach the objectives of an adequate land management, an integrated approach, based on a methodological study and a planning, which permit to find practical and rational solutions to the problems encountered in water scarcity, will be adopted.
The approach is to protect the downstream of watersheds from sedimentation, and floods, and to improve revenues of farmers and livestock herders established in the upper parts of the watersheds. The integrated conservation management will be considered at three levels:

- *Technical and environmental*: It is fundamental to define guidelines to help prevent and fight against water scarcity, and to consider the watershed management techniques which aim at maintaining the fertility of the soil in the watershed and reducing the transport of sediment to the dam reservoirs taking in care environmental aspects.

- *Economical*: In order to make the best micro and macro economical return of the conservation work, it is crucially important to count on the participation of the land-user. It is not expected that this one will change his usual practices unless he perceives that the change is directed towards his interests, that it will minimise his risks and increase his income.
At the macro level, the aim consists of meeting the government objectives of controlling the critical soil erosion situation, moving towards food self sufficiency, and ensuring the best global ratio cost-benefit of the government's investments.

- *Social level*: concern must be given to the support of the local population, as the objective is not only to fight against soil erosion and promote economic growth but is also related to the improvement of the public's conditions especially in the most seriously affected areas where misery, unemployment and under-development are present.

Successful land resource management involves the introduction of changes in farmers' behavioural patterns. Therefore the principal benefit of this approach is to give small and medium scale farmers the opportunity to breakout of the vicious circle of abusive cereal cultivation which decline production yields and accelerate soil erosion by adopting an improved farming system based on animal production.

CASE STUDY Tul Karem / Emek Hefer
Title: Tul Karem / Emek Hefer
Type of case study: local example
Objective of case study – Given ongoing regional water scarcity in the Middle East, efforts to protect existing resources from pollution are particularly important. Unfortunately, in the context of Israeli-Palestinian relations, these efforts are often hampered by the conflict and lack of cooperation. Owing to the transboundary nature of local water resources, their protection cannot be achieved without cooperative action. This case study demonstrates an innovative way to overcome difficulties associated with the conflict when it comes to protecting shared water resources through unique cooperation between local municipalities, supported by civil society groups from both sides.
Contribution … Friends of the Earth Middle East
Characterisation The Palestinian city of Tul Karem is located in the north western West Bank, adjacent to the green line: the 1967 cease-fire line representing the boundary between Israel and the West Bank. Across that line is the Israeli Regional Council of Emek Hefer. In recent years, a separation barrier, consisting in part of a concrete wall and in other parts of a system of fences, was established between Palestinian and Israeli populations, completely preventing passage of people and vehicles. However, sewage from the West Bank city of Tul Karem flows westward, across the green line and underneath the separation barrier, into the Israeli municipality of Emek Hefer. In the past, the sewage polluted the Alexander River, which flows through Emek Hefer Regional Council on its way to the Mediterranean Sea. Alarmingly, the untreated sewage also contaminated scarce, valuable groundwater resources which are shared by Israelis and Palestinians.
Experiences gained - Conclusions - Recommendations Addressing this issue, the Mayors of both municipalities signed in 1996 a Treaty of Intentions outlining their mutual interest and initial plans for regional sewage solutions. The local level initiative complemented activities by national governments and their water authorities. Israeli-Palestinian cooperation encountered a significant blow with the outbreak of hostilities in 2000. Government level cooperation continued to take place around water issues, however it was insufficient to solve the sewage pollution. An emergency facility was built unilaterally by Israel, funded by tax revenue owed by Israel to the Palestinian Authority. However, the treatment provided was insufficient and required additional components. Ties between both mayors were also initially severed, but were soon reinstated with the help and initiative of Friends of the Earth Middle East (an NGO) and another (Israeli-Arab) neighbouring Mayor. The two mayors succeeded in transcending the new reality, and facilitate the establishment of pretreatment facilities for Tul Karem sewage despite the

conflict conditions, with funding provided by the German Development Cooperation. The Tul Karem pre-treatment plant was launched on February 2005, easing the treatment burden in the Israeli side. Among the guests attending the opening ceremony were members of both communities.

This project could only be facilitated through the cooperative effort of the local municipality, German assistance and the neighbouring Israeli community of Emek Hefer. The ties established between the two mayors and their mutual interest to find solutions for the pollution threat resulted in a close working relationship that was crucial for successful project implementation. Many conflict related difficulties encountered by donor countries operating in the West Bank could be alleviated through Israeli-Palestinian municipal cooperation, such as coordination with the military, the Foreign Ministry and the Israeli Water Commission which partially controls all water projects in the West Bank. Experience on similar projects during the period of conflict shows that without local level cooperation, progress has been prohibitively slow.

The cooperation between the municipalities is supported by community groups from both sides, through the Good Water Neighbours project carried out by Friends of the Earth Middle East since 2001. As part of the project, youth groups and adult volunteers from both communities carry out educational and practical activities related the water realities in both sides and addressing common concerns of water conservation and protection.

The close cooperation continues to date, with both mayors cooperating to seek additional funding for other additional sewage solution projects. The successful implementation of this project served as an impetus for the continuation of German supported sewage infrastructure in other West Bank cities, hitherto on hold due to the conflict situation.

This case study demonstrates the need for local level cooperation on transboundary water management, particularly in conflict situations where national level cooperation is often inadequate. It further demonstrates the need for international development funding for protecting scarce water resources from pollution. In addition, it highlights the contribution of community groups and NGO's from both sides of a conflict divide to the protection of scarce water resources.

Outlook - Next steps – Accessibility of results

The continuation of both conflict conditions and water scarcity in the Middle East are a matter of fact for the near future. In fact, cooperation between governments in the region has significantly deteriorated. Sustainable management of water resources under scarcity, an issue traditionally in the domain of national governments, requires the involvement of local actors, at the municipal and community level.

3. CHAPTER III: LONG TERM IMBALANCES IN SUPPLY AND DEMAND

3.1. Introduction

The following chapter deals with long term imbalances. This chapter allows to share knowledge on different instruments on the demand side (water saving, water reuse, reduction of leakages…) and on the supply side (reservoirs, dams, water transfer…). The EU water directors have clearly expressed the priority on demand side instruments before creating resources. This document reflects also the direction promoted by the WFD: the integrated river basin management (IRBM). It is clear that if the WFD is not directly transferable in the Mediterranean, some of its tools and instruments could be adapted with benefits in the Southern part of the Mediterranean. The integrated vision of water management, the building of programme of measures and associated river basin management plans dealing at the same time with quantitative and qualitative issues could be of added value for non EU Mediterranean countries. In these countries a special attention to social affordability of proposed measures should be given. Social and economic impact of scarcity for household and agriculture could be highlighted. Therefore specific measures are of particular interest in the region, such as demand management ones: waste reuse for agriculture, rainfall storage, desalinization, reduction of leakages for agricultural channels and urban networks, new techniques of irrigation as well as water storage (dams, aquifers, reservoirs,), aquifer recharges. The impacts of tourism development should also be given particular consideration as tourism is a key economic sector (218 million per year, Plan Bleu, 2005).

Examples of measures in Mediterranean countries are given in chapter II. Additional examples of water scarcity and drought management are being analysed through Mediterranean research[12] and MEDA projects. The MEDA water programme[13] intents to improve local water management conditions through co-operation of non-profit organisations from EU countries and non-profit organisations in the MENA countries, capacity building, construction of demonstration plants, technology transfer and creation of awareness. It aims mainly at three technical components, (i) water supply and wastewater reuse (in agriculture and in an urban set-up), (ii) irrigation water management and (iii) improvement of decision-making structures in irrigation, rural water supply and sanitation, and drought management.

In water stressed areas, the limited availability of water resources (depletion of some resources and loss of others due to pollution) and increased water demands (greater variety of uses and users) are the main causes of water scarcity problem. Remedial measures used to be based on the development of new water resources to offset the increasing demand. However, the ever increasing abstraction of the limited resource, in order to deal with a growing scope of multi-disciplinary uses and avert global heating hazards, have stimulated a new management strategy, mainly economizing water rather than working out new water resources. To reach the goal of a sustainable water management, balance has to be achieved

[12] Such as WaterStrategyMan, http://environ.chemeng.ntua.gr/wsm/ ; AQUASTRESS, see http://www.aquastress.net/index.php; etc.
[13] See http://www.medawater-rmsu.org/Default.asp

between abstractive uses of water (e.g. abstraction for public water supply, irrigation and industrials uses), in-stream uses (e.g. recreation, ecosystem maintenance), discharge of effluents and impact of diffuse sources.

This new concept is defined as an Integrated Water Resource Management (IWRM) approach that promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems (Global Water Partnership, 2004). This approach is not only about "managing physical resources" but also "reforming human systems to enable people to benefit from the resources".

Within the EU territory, WFD is a good first step towards this approach in terms of quantitative management of water. Throughout the program for the monitoring of surface water and groundwater status and protected areas (article 8) and throughout the programme of measures (article 11), WFD proposes an IWRM approach. Moreover, quantitative aspects are mentioned several times in these articles. WFD gives a framework for long-term changes on quantitative management in order to deal with long-term imbalances between supply and demand, recalling that "all practical steps are taken to prevent further deterioration in status" (article 4a).

These practical steps can be divided into two types of measures:

- Measures for fulfilling demands using available water
- Supply side measures

3.2. Type of Management Measures for balancing Demands Using Available Water

The relationship between water abstraction and water availability has turned into a major stress factor in the exploitation of water resources in Europe and in the Mediterranean. Therefore, it is logical that investigation on sustainable water use in application of WFD is now reoriented on the possibilities of influencing water demand in a favourable way for the aquatic environment.

Integrated Water Management (IWM) is the new paradigm for a wish of efficient, sustainable and safe supply of water. IWM usually means inter alia the use of the best water quality for each demand, so different uses can be supplied with different qualities of water. Water has to be collected from different sources and retorted to their end-users as efficiently as possible. Nevertheless, in order to get real IWM from the demand side, it is also necessary to consider the Shadow Water (SW), the water that, as a consequence of best practices, we don't need to use. The water we don't have to produce, the water we prevent from leaking from the network, the water we avoid using and that we don't have to clean is Shadow Water, the best water we can achieve for our safe supply, for our environment and also for our economy.

Probably, many of these assertions would be discussed on a short-term and economic basis, but in a global and long-term prospect, they are unquestionable. Action towards a sustainable future has to be founded on the use of IWM based on raising the offer of SW versus Real Water. In fact, the ratio between these two types of water is an indicator of the water supply quality.

Many experiences already exist in the "production" of SW. Some of them have been quantified in different situations and we are able to consider some of its advantages and difficulties. Cost estimations are time dependent, as many of them could be considered as long-term investments which clearly overcome company budgets.

3.2.1. Demand-side measures

Demand-side management is already well developed in other economic sectors like electricity, gas or oil. Efficiency standards, product labelling and advice services to users are good examples of actions set up. For example, household appliances are now stamped by the EU Energy Label that rates appliances from A (most efficient) to G (least efficient). However, economic incentives are usually more efficient than these actions. They can enter into account:

- On the price of a good. From example, in France, the electricity provider EDF (Electricité de France) proposes 3 different options: 1st option, a minimum subscription and a fixed price per kWh ; 2nd option, a higher subscription and a reduced price per kWh during 8 hours per day (usually at night) ; and finally 3rd option, the same as the 2nd one with a variability of the reduced price per kWh depending on the period of the year (higher in winter).
- On technology development financing. For example, in France, FIDEME (Fond d'Investissement de l'Environnement et de la Maîtrise de l'Energie) is a €45 millions fund to promote and facilitate the financing of energy saving as well as control and waste improvement projects. The fund is used by subscribing bonds issued by enterprises that develop projects eligible to the fund.

The Plan of Implementation approved at the World Summit on Sustainable Development (WSSD), held in Johannesburg in 2002, included a specific directive calling for all countries to develop integrated water resources management (IWRM) and water efficiency plans by 2005. As Global Water Partnership technical committee stressed in a first version (April 2004) Paper on Guidance in preparing a national IWRM plan, advancing the WSSD plan of implementation inherent in an IWRM approach is the recognition that truly sustainable water resources management involves managing demand, not just supply.

Technological approaches

Water usages can be prioritized according to their ability to answer to human and aquatic environments' needs following the "human basic needs" or the "aquatic environments survival needs" to the "human being needs" or the "aquatic environments best conditions for life". Thus resource waters should be classified over periods of time referring to this prioritization. For example, groundwater, which is usually of high quality, should be reserved for drinking water or more generally for hygiene usages. Surface water collected by dams during winter should at least be used to maintain life conditions (temperature, oxygen,…) during summer and, at best, permit the good functioning of aquatic life cycle like fish migration or access to reproduction zone for example. Thus inter-usage water transfer can intervene in order to answer to this prioritization.

Water saving devices

Water planning, efficiency of uses, quality of the supply, storm water and reuse of water are keystones to improve IWRM. Many of the mistakes of any type of water management come from the non linear pressures on water demand: droughts are medium and long-term unpredictable events. For that reason, water supply pops up in the media just a few months from when a new shortage starts. Consequently, questions and promises of new investments just arise at this time. Many of them drive to quick answers that surely do not constitute the best possibilities for dealing with water scarcity.

Water planning has to be ready for these circumstances, defining what has been done and what is to do in each case by the appropriate person. The reality will probably be different whenever a new case comes up, but we avoid a lot of mistakes and save a lot of water and money if we put on top of the table different previously deemed possibilities.

Efficiency is not only a water management question. Most people could use less water just thinking about this objective. Moreover, we are able to use less water just by changing some of our habits while maintaining our standard of living. Water saving campaigns must inform citizens about how to use water and which level of efficiency we could obtain through already available technology. Pricing of water has to converge towards this objective: above the minimum of needed water, and for a normal standard of living (between 110 and 130 litre per person per day), the price of water has to achieve its full cost for industrial users and be overtaxed for sumptuary users. Total recoveries have to reach the total cost of the water including external factors such as the price we have to pay for aquatic system recovering.
Quality of the supply should agree with well-known standards and guarantee information to consumers. No supply could remain without metering: establishing an account with a minimum of reliability is an absolute requirement. Transparency is the key for a service that is considered as a monopoly for the consumer. In order to increase the quality of the supply, blame and shame policy, as well as an adequate financing, are necessary. A public water board must be considered to audit these services in a consistent way.
Storm water has a promising future as an urban supply complement. Like in the past, collecting water from the roof is a very good practice, especially in residential areas of the cities where family houses are easily prepared for this collection. New technologies for filtering and storing storm water will help end-users to implement these catchments.
Although urban water represents a small percentage of the water consumption around the world, regions that periodically suffer from drought episodes have developed different strategies to deal with supply shortages. Many of them come from the supply side but, as new sources of water become scarce and more expensive year after year, demand policies gain their place in the centre of the debate.
Reuse of water is a common practice in dry regions of the world (Figure 21). Europe reuses over 700 million m³/year. The reuse is considered, in many cases, as the future trend. Indeed, we need to consider different qualities for different uses and to choose the best cleaning process for each purpose. Second quality water has the greatest possibilities for urban supply. A lack of infrastructures is usually a threshold for its development, but we need to establish standards for water reuse in order to include them to new developments. A special focus on water reuse for Mediterranean regions should be given in the future in order to better evaluate the potential of this type of measures.

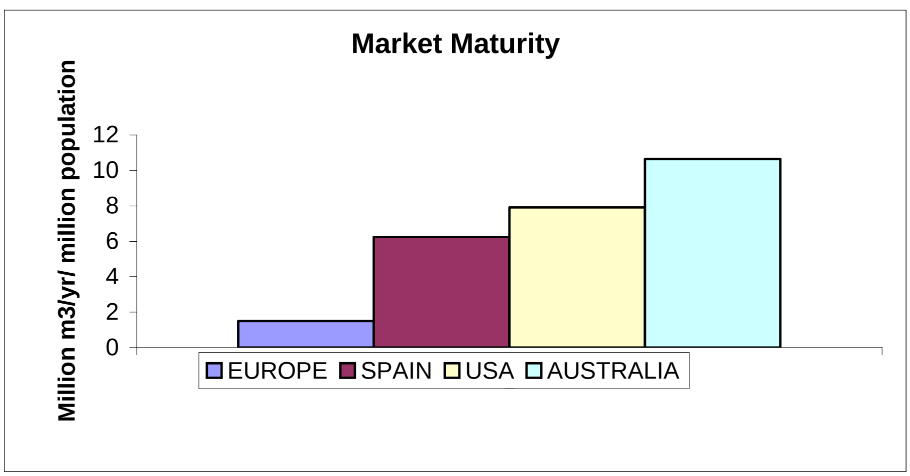


Figure 21: Actual 2002 water reuse installed capacity vs population
European values include Spain. Australian values are for Mediterranean climate States only (Source: Eureau water reuse working group, www.eureau.org)

Water saving devices are often easily usable technologies in households, companies, farms and governmental communities:

- Air devices aim at saving water by pressuring it enough to use less water for the same result (high pressure coach cleaning or high pressure firemen device).
- Thermostats allow avoiding water losses to adjust temperature.
- Double command mechanisms permit to choose the amount of water necessary (double-command toilet, dishwasher cleaning options).
- Timed length of flow regulation system enables water saving with the same efficiency (drop by drop watering).

Water saving devices' impact on water demand varies depending on the importance of water consumption in the activity sector considered. In agriculture, developing water saving devices can strongly impact water consumption especially during irrigation periods. In households, implementing water saving devices would help develop awareness of the necessity of considering water as a scarce resource. However, the impact on water scarcity problems would not be very significant for two reasons:

- Household consumption is usually not the biggest part of water consumption of a country where water scarcity problems occur, especially in Mediterranean context.
- Water saving devices often have difficulties penetrating the market because of the cost of these not widely spread technologies and the slow turnover of home appliances. Long campaigns of information on their availability and advantages are required. Thus, water saving device should be seen as a solution to help economise water but not as the main action of a management plan.

Water metering

Metering water can be the first step towards a succession of actions to reduce water consumption.

- Metering water at waterworks and households permits to localize leakages in the distribution network.
- Because price is often related to the consumed volume when water metering is introduced, water metering is a good way to raise awareness in order to make them economize water resource.

However, it is difficult to estimate the effect of water metering on the decrease of consumption. A 10 to 25 % reduction is estimated as immediate savings from the introduction of water metering (Lallana et al., 2001). This effect certainly depends on the consumer's activity. Householders may not be very regardful whereas those irrigating may surely pay attention because of the relative importance of this charge in spending. This effect depends as well on the mode of pricing. Living standards must be taken into account, or numerous and low income families would have to pay more than wealthy families for the same volume per person and may try to economize so much as to affect hygiene whereas high income family would not be aware of the necessity of saving water.

The impact of the introduction of metering of water consumption is difficult to separate from other factors' effect, particularly the water charges applied. It is also essential to have a correct balance between real water consumption and unaccounted water. Water losses are better measured if a meter is installed at the waterworks as well as at the consumer's home.

However, immediate savings from the introduction of revenue-neutral metering are estimated to be about 10-25% of the consumption, because of the effects of information, publicity and leakage repair, as well as the non zero marginal pricing. Savings are also sustainable over time (WaterStrategyMan – 2005, Guidelines for integrated water management).

The introduction of metering, as part of water demand management, is usually accompanied by a revised charging system and regulation on leakage.
Water meters have usually been used to determine water consumption, but in some countries, such as Denmark, meter readings will be used to calculate a pollution tax, on the basis that water consumption indicates the discharge to the sewage treatment plant.
Introducing water metering to new regions would lead to effects to take into account (effects on socially disadvantaged households which are more vulnerable to water metering and pricing – large family, medical conditions; WaterStrategyMan – 2005, Guidelines for integrated water management).

Leakage reduction in distribution networks

The quantity of water lost is an important indicator of the positive or negative evolution of water distribution efficiency, both in individual years and as a trend over a period of years. High and increasing annual volumes of water losses, which are an indicator of ineffective planning and construction, and low operational maintenance activities, should be the trigger for initiating an active leakage control programme. However, a leak-free network is not a realisable technical or economic objective, and a low level of water losses cannot be avoided, even in the best operated and maintained systems, where water suppliers pay a lot of attention to water loss control. Particular problems and unnecessary misunderstandings arise because of differences in the definitions used by individual countries for describing and calculating losses (IWA, 2000). The problems of water and revenue losses are:

- -Technical: not all the water supplied by a water utility reaches the customer.
- Financial and economic: not all the water supplied is paid for.
- Terminology: lack of standardized definitions of water and revenue losses.

Leakages are difficult to calculate. They can be involved in consumption that is sometimes defined as the abstracted volume of water not restored to water cycle. They cannot be calculated from the invoiced water because volume of invoiced water involves leakages at the consumers' place. They cannot be assumed as equal to losses because losses are not always due to leakages (evaporation in industrial water cooling for example).
Losses in the water distribution network can reach high percentages of the volume introduced. Leakage covers different aspects: losses in the network because of deficient sealing, losses in users' installations before the water is metered and sometimes the consumption differences between used (measured) and not measured quantities are also counted as losses. Leakage figures from different countries not only indicate the different aspects included in the calculations (e.g. Albania up to 75 %, Croatia 30-60 %, Czech Republic 20-30 %, France 30 %, and Spain 24-34 %).
It is possible to use different indices to express the efficiency of a distribution network. Many suppliers argue that a large number of factors should be taken into account in leakage performance and that the indicators described may not be comparable. IWA recommends the use of the Unavoidable Average Real Losses (UARL) index which recognizes separate influences of Real Losses from length of mains, number of service connections, total length of service connections from the edge of the street to customer meters and average pressure when the system is pressurized. In order to evaluate the maximum potential for further savings in Real Losses when the system is pressurised, the difference between the Technical Indicator for Real Losses (TIRL - to be intended as annual volume of real losses divided by the number of service connections) and the UARL must be calculated. Anyway, network meters are generally considered as necessary to enable good network management.
In most rural municipalities, distribution network maintenance is not a priority (lack of regular monitoring, networks plans). This situation coincides with a lower price of water than the national average and a lack of a general use of domestic meters.
Tracing and repairing leakage can be very expensive. Increasing water production to feed leaks may prove cheaper in some systems. The consequence is that local authorities may

decide not to trace leakage despite low efficiency ratios but continue their wasteful use of water (WaterStrategyMan, 2005).
Even the systematic use of acoustic instruments such as “correlators” has its limitations too. The solution could be found in the application of the minimum optimum rehabilitation methods, in which the performance of the network is assessed according to standard of service requirements. Experience has shown that the most efficient and effective way of controlling leakage is to divide the network into a number of permanent districts by closing selected line valves and installing flow meters on the few remaining key supplying mains. In this way, leakage can be continuously monitored and the presence of a new leak identified immediately. In large and complex systems, the division of a network into districts represents quite a delicate operation which, if not undertaken with care, can create low pressure and water quality problems. In order to overcome such difficulties, a fully calibrated network analysis model should be constructed, allowing the design of the districts to be evaluated and optimized before the system is constructed in the field.
Despite the difficulties to identify the most effective measures for leakage reduction, these issues must be considered as a priority among demand-side interventions to be individuated in the programme of measures. Furthermore, the leakage reduction must support the achievement of the water balance at river basin scale.

New technologies and changing processes in industry

Until now, a lot of emphasis has been put on reducing energy use in the industrial sector to reduce costs. It was only during the 1990’s that improving water efficiency also began to be considered as a way of cutting costs. Actions to improve water efficiency are focused on the process and on the discharges.
In a study carried out between 1992 and 1997 in the industrial sector of Catalonia, the Institute of Energy (Catalonia, Spain) found that about 35 % of the proposed cost-saving measures were implemented in areas of management and control, 32 % in the process and only 18 % in the reuse of effluents. By implementing water saving measures, the amount of water saved varies depending on the industrial sector. Following a study carried out by the same institute in 1999, the range of potential water saving is 25 % to more than 50 %. The main findings for industry are as follows:

- The introduction of water saving technologies in the industrial sector is basically focused on the most common processes: cooling and washing.
- Water substitution means immediate savings for an industry (cost savings correspond to the drop in water charges, especially if the substitution did not imply additional investment).
- Improving the control of process conditions can reduce water consumption by about 50 %.
- Work in closed circuits can reduce water use by about 90 %.
- A reduction in the cost of the existing water saving technologies could encourage further extension to small industries.
- Better communication between industries with high water consumption may help to disseminate pilot project results on water saving technologies.

New technologies and changing processes in agriculture (examples of irrigation methods in some countries)

Irrigation permits to increase culture production on one hand and partly prevent from climatic hazards on the other hand, obtaining a more stable output and a better quality. It also allows decreasing risks on agricultural income. Water withdrawals for agricultural irrigation have clearly increased since 50 years in southern Europe countries and mostly happen in summer (low water period) when water is not very available. They are thus conducive to create or enhance water shortage harmful for the other resource users and natural systems.

A reduction of agricultural withdrawals can be achieved through:

- A reasoning of irrigation with a precise adaptation of the amounts of supplied water: launching of irrigation from an irrigation balance, estimation of the existing cultivations needs, irrigation recording book, etc.
- Leakage limitation by drain, infiltration, evaporation or drift: gravity irrigation suppression localized irrigation development (drop by drop) when possible, equipment adjustment, no irrigation during maximum sunshine or when wind blows over 7 km/h.
- Collective management of disposable resource for agriculture.
- Changing the type of crops: less consuming or differently distributed in time (winter cultivations instead of spring ones).

Better control of irrigation

In order to achieve a balanced water resource management and a better knowledge of the pressures, removed water counting is necessary. It is an essential tool to pilot the irrigation and permits to know the actual amounts of withdrawals and consequently allows:

- An adaptation of water supplies according to actual needs for cultivations and soil specificities.
- The control of the good functioning of irrigation devices (leak spotting for example).
- To give the opportunity to local stakeholders to set up a planed and umpired management of the resource for all users.
- To make money savings by diminishing the removed volume.

However, it is advisable to insure an as precise as possible counting, by means of maintenance and regular standardization of the counting devices.

Over the last decades, major efforts have also been made to adapt water consumption of irrigation to water needs of the crops, in relation to its variety and lifecycle. Traditionally, the UN FAO methodology was calculating the theoretical crop evapotranspiration. But water efficiency technologies have significantly improved over the last years and current methods are more precise to determine water requirements of the crop via analyzing soil humidity, plant and climate. Strategically placed control sensors measure humidity in the upper soil layers and the trunk at a high frequency. These data are transmitted to a central control station and combined to meteorological data from a climate station close to the plot.

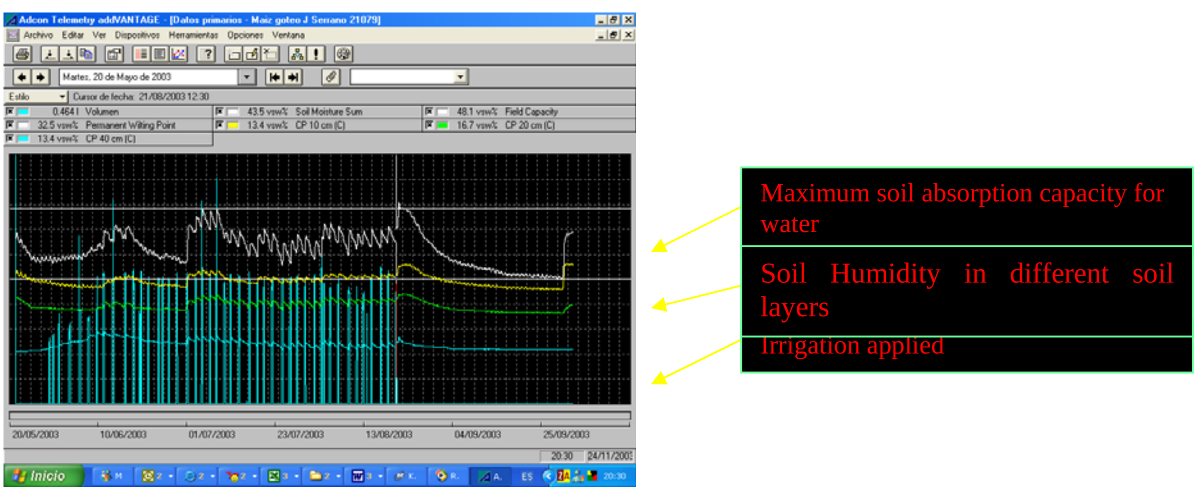


Figure 22: Example of a register of irrigation and soil humidity (WWF & Acciones Integradasde Desarrollo, 2005 : Proyecto LIFE Hagar. Madrid)

The resulting graphs show soil humidity and water absorption by the crop, facilitating the establishment of much adjusted irrigation recommendations (Figure 22). The frequency of irrigation can avoid water losses by infiltration and ensure that the soil is always partially humid. This control of the plant access to water is an ideal way to develop production objectives regarding a certain crop quality.
This method has been applied in different projects. In EU LIFE pilot project (www.life-hagar.com) in Castilla La Mancha (Spain), 12 plots of vineyard, onion, alfalfa, sugar beet and melon crops have been studied with soil humidity sensors (C-probes FDR), irrigation control, water meters, precise dendrometers and climate stations. The average water saving is 14 %, with a range of 4 to 30 % according to the crops. These savings are significant in an area with constant overexploitation (total deficit of 5500 Hm^3) and high water pumping costs. In the orange and mandarin Los Mimbrales estate (Huelva, Spain) immediately upstream the Doñana National Park, 30 % of water have been saved.

<u>Improvement of irrigation technologies: switching from gravity to pressurized irrigation and other technologies</u>

The irrigation industry is rapidly developing new technologies to make irrigation more efficient. It is important to keep in mind that there is no one best irrigation method for all conditions. Any method can work efficiently if it is appropriate to the circumstances, well designed, and diligently maintained. In all cases, the proper application amount equals the water required by the crop, plus the water needed to prevent the build-up of harmful minerals in the soil through a process called leaching. It helps prevent waste, minimize run-off and lessens the effect of drought. "Smart" technologies, like systems with flow-control nozzles, climate-based controllers and automatic shutoffs are beneficial and even required for irrigation systems in some areas. More and more communities are moving toward rewarding or requiring new irrigation systems to include more water-wise features with irrigation systems that deliver exactly the right amount of water at the right time. The benefits of an automatic irrigation system include:

- reduced labour for watering
- convenience
- full landscape coverage
- easy control over irrigation timing for overnight or early-morning watering
- added value to home or business property
- minimized plant loss during drought

Traditional irrigation system controllers are really just timers. They turn the water on and off when they are told, regardless of weather conditions. Smart irrigation controllers, on the other hand, monitor and use information about environmental conditions for a specific location and landscape -information such as soil moisture, rain, wind, the plants evaporation and transpiration rates, and, in some cases, plant type and more - to decide for themselves when to water, and when not to, providing exactly the right amount of water to maintain lush, healthy growing conditions. Because smart irrigation controllers are more efficient than traditional, timer-based controllers, they also reduce overall water usage, typically by 30 %.
Gravity flow surface irrigation is the spreading of water over a basin or along furrows by gravity flow. Earthen borders check the spread. There may be pumps at the tail end of the field to recycle excess water (if there is any). Fields should be prepared so they are level or slightly and evenly sloped. A farmer can calculate the amount of water to apply (irrigation scheduling) by noting the field dimensions, crop, stage of growth, climate conditions, and soil dryness. The objective is to minimize the water lost beyond the reach of plant roots and the excess water pumped from the tail end of sloped fields. Farmers close to rivers can drain their excess tail water to the natural channel or let extra water percolate below the plant

roots underground back to the river, thus helping to replenish the quantity of the river flow. However, the return water carries sediment, soil salts, chemicals and fertilizer, all of which diminish the water quality in the receiving stream. Careful water scheduling benefits the environment by reducing both diversions and runoff. Since less water is diverted, less power is required to pump water to the fields.

Pressurized sprinkler irrigation is the distribution of drops of water over the crop, imitating rain. For permanent installations, pipes can be laid on the ground or buried (solid set). For mobile installations, pipes may be moved by hand or supported by wheel structures that advance the sprinklers along a field (linear moves, wheel lines). Center pivot systems, similar to linear moves, rotate about well heads that supply water from underground rather than from canals. Sprinkler systems are well suited for uneven terrain. These systems apply water most uniformly when there is little wind; windy conditions can spoil the application pattern. Careful monitoring and water scheduling reduce over-watering. For linear moves, downward oriented drop tubes deliver water closer to the crop with less wind scatter. The objective is to match the application rate to the infiltration rate, so that the soil is wetted without water pooling upon the surface where it evaporates or runs off the end of the field. Sprinkler irrigation can serve many purposes: frost protection, seed germination, leaf canopy cooling, delivery of agricultural chemicals mixed with the irrigation water and replenishing soil moisture during the off-season. But pressurized, elevated pipes also require expensive electrically powered pumping. The degree of application uniformity determines the efficiency of a sprinkler system. When water is unevenly distributed, supplying sufficient water to the least watered areas results in everywhere else being over-watered. Compared to surface irrigation methods, sprinklers permit better control over application amounts. Low pressure micro-irrigation delivers water drop-by-drop right to the root zone so the plants take up water gradually from their roots. Low pressure tubes allow water to seep through tiny perforations (emitters). Drip tapes and rigid drip tubes are rolled out over the surface, or buried under the soil surface. Mist sprayers are used to apply fine droplets beneath the leaf canopy, directly upon the soil. This method can be the most efficient crop watering method when the system is designed for:

- even application across the irrigated area
- careful timing to prevent over-watering
- water filtration to keep the emitters clean

The high cost of installing and maintaining a micro-system is justified for permanent high value crops such as vineyards and orchards. As technological innovation reduces the cost and as water prices rise, micro methods will find further application.

<u>Quota control</u>

The water quota system is used to define the limit on water use or establishes how much to use, when, by whom, and for what purpose water can be augmented and used. When users' behaviour is not very responsive to price changes, because of rigid price elasticity, or when uncertainty is involved in the computation of marginal cost and benefit, quota regulation is suggested as one of the measures for controlling water use (Tsur and Dinar, 1997; Mohamed and Sevenije, 2000). The difference between the quota and pricing system is that in the former case, the marginal social costs associated to each unit of abstraction are assumed to be minimal through the setting of some standards. Likewise, the basic difference between a quota and right allocation is that the former may have various attributes, including a pre-determined price, and be subject to modifications, based on external conditions and number of users, or participants (Tiwari and Dinar, 2001).

Water reuse

Reclaimed water is an alternative water resource[14]. Water reuse can be a tool in managing scarce water resources. Recycled water is being used as substitute for many traditional non potable uses and for sources that provide raw water for drinking water production (table 14). Such use can help conserve drinking water by replacing it or the water taken from drinking water sources, and by enhancing sources such as reservoirs and groundwater. The improvements in treatment of wastewater have opened new possibilities to reuse treated wastewater. Hence, the indirect recycling of water used in many parts of the world has been largely practiced for many years.

There are no formal European wide guidelines, best practice or regulations for water recycling and reuse other than the Urban Wastewater Directive which requires that “treated wastewater shall be reused whenever appropriate” and "Disposal routes shall minimize the adverse effects on the environment” (article 12). The EU needs suitable guidelines and definition of “whenever appropriate”. This should however be seen in the light of the objectives of the directive (article 1): “…to protect the environment from the adverse effects of waste water discharges”. Significant progress has been made through initiatives in some member states. To maintain the momentum gained, the valuable initiatives in Cyprus, Belgium, France, Spain, UK and other Mediterranean countries should be used as a base to develop water recycling and reuse guidelines and codes of best practice.

	Definition
Reclaimed water	Treated wastewater suitable for beneficial purposes such as irrigation
Reuse	Utilization of appropriately treated wastewater (reclaimed water) for some further beneficial purpose
Recycling	Reuse of treated wastewater
Potable substitution	Reuse of appropriately treated reclaimed water instead of potable water for non potable applications
Non-potable reuse	Use of reclaimed water for other than drinking water, for example, irrigation
Indirect recycling or indirect potable reuse	Use of reclaimed water for potable supplies after a period of storage in surface or a groundwater
Direct potable reuse	conversion of wastewater directly into drinking water without any intermediate storage

Table 14: Water recycling and reuse definitions

The potential of reuse in Europe is high, especially in Spain, Italy, and to a lesser extent in France, Portugal, Greece, Poland and Belgium. For example in Spain, a maximum water reuse of 2000 Mm3/year could be reached (Hochstrat et al., 2005).

Applications

Although treated wastewater has been an important mean of replenishing river flows in many countries and the subsequent use of such water for a range of purposes (Figure 23) constitutes indirect reuse of wastewater, it is becoming increasingly attractive to use reclaimed or treated wastewater more directly. In addition, reclamation of wastewater is attractive in terms of sustainability since wastewater requires disposal if it is not to be reclaimed (UKWIR et al., 2004).

[14] See AQUAREC project www.aquarec.org

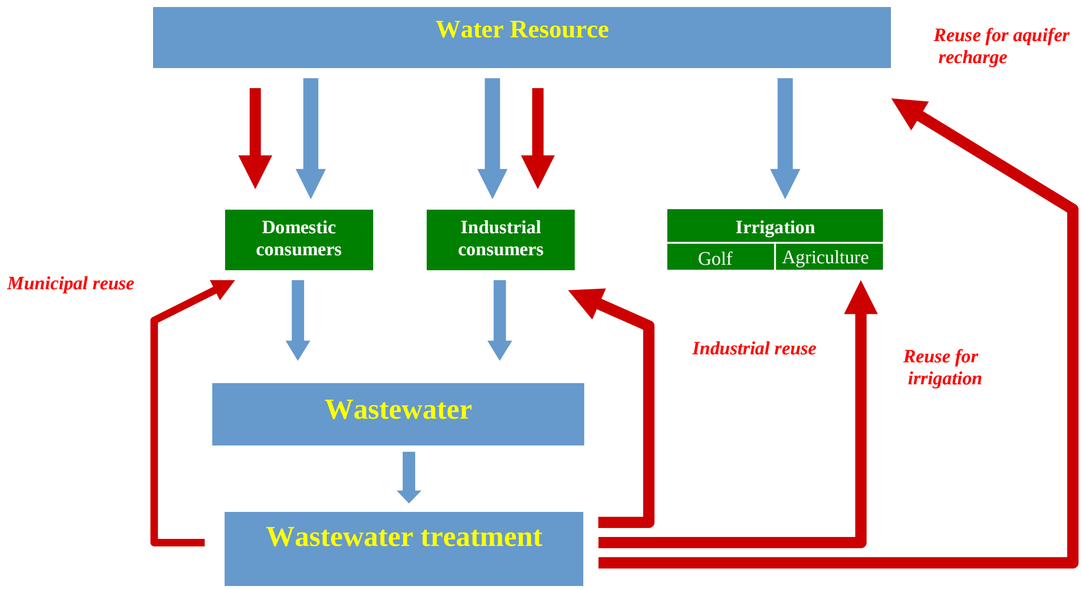


Figure 23: Different applications of reuse

Treated wastewater may be used as an alternative source of water for agricultural irrigation. Agriculture represents up to 60 % of the global water demand while the requirements arising from increasing urbanization such as watering urban recreational landscapes and sports facilities, also creates a high demand: water scarcity in Mediterranean countries historically led these countries to appropriately use treated wastewater in agriculture, irrigation of golf courses and other green spaces, including those used for recreation in which individuals may come into contact with the ground. It can be used to supplement artificially created recreational waters and for reclamation and maintenance of wetlands for which there can be a significant ecological benefit and a subsequent sense of profit to the community. Concerns related to the reuse of treated wastewater are similar to the reuse of sludge, in particular the risks of contamination. Treatment plants are typically only equipped for biological treatment which does not eliminate the chemical substances in the waste water.

In urban environments, treated wastewater may also be used for fire-fighting purposes or street cleaning. In industry, the use of recycled or reclaimed water has extensively developed since the 1970's, for the dual purpose of decreasing the purchase of water and avoiding the discharge of treated wastewater under increasingly stringent emission regulations. This trend started with wash-water recycling but now incorporates the treatment of all types of process waters. Virtually, all industrial sectors are now recycling water, with examples in pulp and paper, oil refinery, etc. Consequently, together with overall shifts in the industrial sector, a 30 % reduction of industrial water consumption has been achieved in some European countries. Where water is scarce, industries also use reclaimed municipal water to reduce their production costs.

An additional use may be the direct supplementation of drinking water resources through groundwater infiltration and by adding it to surface water, with examples in northern Europe where several cities rely on indirect potable reuse for 70 % of their potable resource during dry summer conditions. It is even technically possible to use reclaimed water as a direct drinking water source, although acceptability of the public may not be achievable yet.

The first priority to consider, with regards to the benefit and the public acceptance, is the recharge of surface and groundwater bodies. This form of indirect reuse is a common practice: artificial recharge of groundwater for saline ingress control, or potable resource enhancement, such as in Flanders. Potable substitution is the second priority for any non potable application such as:

- reclaimed water for industry (for cooling water make up, process water to reduce manufacturing costs
- agricultural and urban irrigation, to increase productivity and increase the value of amenities such as parks, sports fields, golf courses as well as domestic gardens on new developments, and finally agriculture itself.

Public health and environment protection

The protection of public health is the key issue associated to water reuse. In addition to public health risks, insufficiently treated effluent may have detrimental effects on the ability to grow irrigated crops. The main risk associated to reuse in irrigation is a short-term hazard associated to the presence of pathogens in the water. The World Health Organisation (WHO) has set guidelines for water reuse in irrigation, mainly based on fecal coliforms and helminth eggs counts, with quota adapted to the use for crops.

In Europe, a few member states (where reuse is necessary for irrigation, like in Spain, Belgium, Italy and France) had to overcome the absence of European guidelines or regulation by creating their own national regulation. These standards are based on the WHO guidelines and necessary conservative assumptions, the later leaving room for extremely severe requirements. It is worth noting that, in contrast with some other standards such as the Californian Title 22, member states standards for reused water are not based on technology.

For direct or indirect drinking water supply, the Directive 98/83 is applied with very strict standards for pathogens and chemical contaminants, therefore offering a high level of public health protection. There is however some concern that the current standards and guidelines were not designed to deal with the mixture and individual contaminants that are unique to wastewater sources and water catchments recharged with treated wastewater. Endocrine disruptors, pharmaceuticals, disinfection byproducts and pathogenic bacteria, viruses and parasites, and genetically engineered products might be present at levels relevant to public health.

Hence, beyond the strict legal requirements for compliance with maxima designed for various types of uses, there is a shift towards water safety plans which are based on a risk assessment of the entire water cycle from source to final user. This incorporates a thorough analysis of the raw water quality parameters and protection measures, the individual treatment steps, their capability to remove the targeted pollutants, and the distribution system up to the point of use. This methodology uses the Hazard Analysis and Critical Control Points (HACCP) approach where the multiple barriers appear as the preferred approach to minimize risks to an acceptable level, in addition to the complementary water quality control.

The opportunities for water reuse should also avoid or minimize environmental impacts to biological, hydrogeological and cultural resources, and to land use due to the construction or operation of reuse facilities.

Technologies

All types of technologies are used to reclaim wastewater, depending on the initial pollutant type and concentration, and treated water quality to be achieved. Stringent control of water quality and operational reliability are the main requirements which drive the technological choices. The most well-known example of reuse in Europe is the supply of drinking water through bank filtration, where the local geology (soil aquifer treatment) and land protection regimes authorize the use of surface water situated downstream of wastewater treatment plants. In such cases, the natural processes taking place in the bank safely remove the pollutants and pathogens. Whenever needed, these natural processes may be complemented by filtration on granular activated carbon for pesticides and ozonation for micro-pollutants removal.

One third of the water reclamation schemes rely on secondary treatment of municipal sewage. This level of treatment usually fulfils the requirement of cooling water in the industry, or irrigation water where the food crops are consumed after cooking. One has to mention the possibility offered by membrane bioreactors, which can replace the secondary treatment, while enabling to meet disinfection requirements. Other advanced treatment may replace traditional secondary treatment for reuse purposes.

More often, some kind of tertiary treatment is required to meet the industry or irrigation standards, especially in the later case where disinfection is needed. Disinfection may be achieved by oxidation with chlorine, ozone, or more recently ultraviolet irradiation. Granular activated carbon is used where micro-pollutants are likely to be present.

The last case involves a quaternary treatment with membranes. The most common processes involve either microfiltration (pore size of 0,1 µm) or ultrafiltation (pore size of 0,01 µm), which also removes viruses. These treatments are the favourite technologies on sewage for the removal of suspended solids, particles, bacteria and parasites. In addition, nanofiltration (pore size of 0,001 µm) or reverse osmose membranes (pore size of 0,0001 µm) are used when soluble materials such as salts or dissolved organic matter have to be removed, in order to achieve drinking water quality or ultra pure water quality for industry.

A combination or hybridization of different centralized or decentralized technical solutions is needed to reach the specific objectives when considering the local water cycle. The issue is not the availability of technology but the vision, experience and institutional infrastructure needed to recognize and implement reuse solutions. These needs to build on the synergy between natural and technological solutions that protect public health and the environment, reduce costs and energy demand to treat and transport water.

In the interest of managing both known and unknown risks, advanced water treatment processes are increasingly being deployed in recycled water projects to provide added assurance that unknown risks are mitigated.

<u>Water reuse benefits</u>

Water reuse benefits all segments of the anthropogenic water cycle and should be considered as a horizontal application that pulls together the normally segregated disciplines of potable water and wastewater treatment for economic development, public health and environmental protection. Water reuse reduces the competition for water between agriculture, public and industrial supplies by increasing the available water resource and can be used as an effective cohesion tool across Europe and the Mediterranean. Water reuse benefits are:

1 - Decrease of net water demand and value addition to water
2 - Potable substitution: keep potable water for drinking and reclaimed water for non potable use
3 - Lower energy costs compared to deep groundwater, importation or desalinization
4 - Reduction of manufacturing industries costs by using high quality reclaimed water
5 - Valuable and drought proof alternative water for industry and irrigation
6 - Reduction of nutrient removal costs to protect the surface waters through irrigation
7 - Reduction of nutrient discharge to the environment and loss of freshwater to the sea
8 - Increase of land value when developing brown field sites and with drought proof irrigation

9 - Increase of local ecological benefits, flood protection and tourism through the creation of wetlands, urban irrigation, bathing beach protection and reduction of the need and cost of long sea outfalls
10 - Control of the problems of over-abstraction of surface and groundwater
11 - Management of the recharge of surface and groundwaters to optimize quality and quantity
12 - Integration of all parts of the anthropogenic water cycle to enable cohesion between all regulators and industries across Europe.

Enabling the growth of water recycling and reuse

It is essential that the development of water recycling and reuse in agriculture and other sectors be based on scientific evidence of effects on environment and public health. The EU needs a regulatory and institutional framework tailored to suit local needs to take advantage of the water recycling and reuse opportunities, and to help overcome the water shortage problems regarding cost-effectiveness. These regulatory principles could be transfer with some adaptations to Mediterranean non EU countries .It appears necessary to provide a comprehensive guidance document to ensure that any risk is minimized and that valuable knowledge is available for any organisation considering the implementation of a water reuse project.

In line with the WFD 2000/60/EC, civil society and stakeholders must be involved so that they understand and fully contribute to the decisions. The consultation required by directive 2000/60/EC creates a momentum for a better understanding of the water cycle, upon which local projects should be built. For any project, the safety of the product and the systems has to be proven, and the solutions must be justified and sustainable from environmental, economic and social point of view. This can be achieved by the publication of clear and accurate documents on the anthropogenic water cycle to overcome the lack of understanding of drinking water, wastewater, water resource planners, environmental fraternities, politicians and the public.

The promotion of water reuse would benefit from clear guidance and best practice documents from the European Union authorities (Durham et al., 2005).

DG Environment of the European Commission recognizes that wastewater reuse has a potential role to play in the efficient and integrated use of water resources and is one of the actions that need to be undertaken for a more effective water management. A preliminary discussion on this issue took place at the EU Water Directors' meeting in Luxembourg (June 2005) and a Mediterranean Working Group has been set up[15].

Several research projects[16] (UKWIR, 2004) provide the initial material for such a work, and workshops[17] have already been organized in Europe on the various aspects earlier described in this document. In the drafting of the guidelines, several points need to be precisely addressed. Beyond an accurate description of the anthropogenic water cycle, the benefits and risks of water reuse for different purposes need to be clearly explained. Moreover, the guidelines should provide a framework for new projects implementation, since local authorities and stakeholders normally do not have the experience to handle the various tasks involved. Consideration should also be given as to some new legal requirements or financial incentives to allow Water Districts to encourage or favour water reuse projects.

In addition to the appreciable amount of experience gained in Europe, the realizations and institutional set-up in other water stressed regions of the world such as the USA, Australia and Singapore, could provide some useful complementary concepts. As an example in Australia, an achievable target of 20 % reuse of wastewater by 2012 has been set in some

[15] In the framework of the Med-EUWI / WFD Joint Process, a Working Group on Waste water reuse has been set up, see http://www.emwis.net/topics/WaterReuse
[16] In particular: AQUAREC, CORETECH, MEDWATER
[17] By UKWIR, EUREAU, AEAS Spain among others.

territories to highlight the importance of reuse and focus regional strategies (Durham et al., 2005).
Finally, water scarcity solutions need to include economically justifiable water saving and demand management techniques rather than immediately searching for new water resources. Water reuse is one of a large number of alternative solutions but is important when considering the objectives of the WFD as water reuse is proven to increase water availability and reduces surface water eutrophication. Agenda 21 and the widely agreed need to recycle waste materials are dynamically being promoted and implemented across Europe. It can be argued that water recycling has a higher impact on European sustainability than paper, glass and metals recycling and Europe does not have guidelines yet to help innovators to sustain recycle water.

Economic approaches

Demand-side management efficiency is rather due to economic actions (research financing, subsidies for efficient products, regulatory price controls, price incentives) and legal obligation than to public awareness actions. Economic actions are often the result of public intervention in the sector and public intervention policy depends on the sector and the country. Thus, the mode of intervention, direct incentives (taxes) or indirect incentives (fiscal instruments), must be adapted.
Economic actions are often a way of promoting one technology more than another. Distortion in prices, taxes or subsidies leads to competitive advantage of a service or a product to the detriment of another one. The consequences for non beneficiary companies have to be foreseen. These incentives can be proposed not only for alternative technologies but, as well, for programs that could be developed by non beneficiary companies to reduce their clients' consumption, for process evolution or for activity diversification of these same companies. Attention must be paid on the choice of the technology that receives economic help because the cost of a technology is often difficult to estimate and some technologies are already helped through indirect incentives.

Impact of agricultural policies

The increased water demand in agriculture has been stimulated by numerous causes, including farmers' response to market demands or in certain cases agricultural subsidies - often under the EU Common Agriculture Policy frame (CAP) - that support certain production.
The EU and National agricultural policies orientate water consumption in several ways:

- by differentiating subsidies for irrigated and non-irrigated crops
- by investing into irrigation systems through rural development funds
- by paying export subsidies, often used as means to deal with European over-production, and often in sectors in which volumes of production are directly linked to irrigation (e.g. tomatoes)

There have been CAP reforms in the past few years, and these have -in part- diminished the direct link between subsidies and volume of production (and therefore irrigation). The direct payments for arable areas are now fully decoupled except for only two member states (France and Spain), which have decided to keep these payments coupled at the level of 25 % allowed by the Community framework. Indeed majority of MS didn't follow fully the Commission's ideas on de-coupling.
In order to reduce the effects of droughts and water scarcity, measures to promote adapted agricultural production such as low water requiring crops are needed. Furthermore, and in order to minimise drought impacts on water bodies, the cross-compliance review in 2007 must include WFD standards as a baseline for cross-compliance.

Furthermore, some of the water-demanding agricultures still have to be reformed within the framework of CAP, including the wine and horticultural sector. Reform proposals will be tabled in due course. Although there are no direct subsidies in the Fruits & Vegetables sector, there are payments to help producer organisations operate and also to place products on the market, as well as export subsidies (but there are many other measures possible, e.g. similar to agri-environment). The planned reforms should take into account the effects of the agricultural subsidies on water consumption, especially in water-stressed areas. Here again the issue of respect of water (abstraction) standards comes in.

Examples of pricing methods for irrigation in different countries

Irrigation has a different purpose in different geographic and climatic areas of Europe. In southern European countries, irrigation is necessary to secure crop growth each year, whereas, in central and western Europe, it is used to maintain production during dry summers. These different roles are important when analyzing water pricing policies in the agricultural sector because these policies are often derived from more general policies (economic and social development in rural areas). This difference is also important when comparing agricultural pricing policies between countries or regions.

The situation regarding water tariffs for irrigation is often very different from other sectors:

• Irrigation tariffs can be extremely low and there is significant lobbying pressure to resist any increase

• Water use in the sector has been subsidized in most of the countries (subsidies as a tool for developing irrigation for food production and/or social development)

• Tariffs can be based on forfeits

• Meters may not be installed on many abstractions or uses

• Public pressure concerning the environmental image of agriculture is much less than for industry for example

Most agricultural water prices distinguish between charges for water resources and charges to cover part or all of the cost of water supply for irrigation. The aim of the former component is to ration water use (especially if it is scarce), while that of the latter is to guarantee that the supply system is financially self-sufficient. Nevertheless, it is only in the regions where water is scarce, and as a consequence is a tradable good, that water prices tend to reflect their scarcity values, as distinct from supply cost (OECD, 1999). The cost of irrigation water supply consists of the variable costs of processing and delivering the water to end-users and of the fixed cost of capital depreciation, operation and maintenance. Variable costs depend on the amount of water delivered, while fixed costs do not. In most countries, fixed costs are heavily subsidized (UN, 1980).

The method by which irrigation water is delivered affects the variable cost, as well as the irrigation technology applied and the feasible pricing schemes. The irrigation water in a region is often delivered by more than one method, depending on tradition, physical conditions, water facilities and institutions (UN, 1980). The most common system for irrigation charges is based on the irrigated surface, followed by a combination of per unit area and volume used.

The adoption of more efficient irrigation technologies is accelerated by higher water charges but also other factors such as land quality, well depths, and agricultural prices, are just as important, if not more so, than the price effect of water itself.

Subsidies for the rehabilitation of irrigation districts and for new irrigation technologies might end up increasing farm water consumption. Although water productivity could increase, total water consumption at the level of the basin might also increase, unless allocations are simultaneously revised downwards.

In general, the amount of water used for irrigation moderately responds to water price levels but is more influenced by factors such as climate variations, agricultural policies, product prices or structural factors. Cross-sectional studies of irrigation districts, at both national and international levels, have found conflicting evidence of the influence of water price levels on water management efficiencies (OECD, 1999).

Economic incentives/fines

Essential elements of water demand management programmes in the urban context are measures dealing with economic incentives. Price structures are generally fixed at municipal level and can widely vary within a country. The differences, in general, take into account different types of users (e.g. domestic, industrial and agricultural) and tend to reflect differences in cost structures.

There is a huge variety in the types of metered tariff which can be used (Pezzey and Mill, 1998). The main types of tariff structure (excluding the initial connexion charge) are:

- Flat-rate tariff
- Uniform volumetric tariff
- Two-part or binomial tariff (sum of a flat-rate tariff and a uniform volumetric tariff)
- Block tariffs, which also usually incorporate a flat-rate charge, plus declining block tariffs and rising block tariffs

Frequently, tariffs include a basic allowance (charged at zero or a low rate) to allow equity concerns. A minimum charge for a volume consumed can also be applied. The same or different tariffs may apply to different types of users. Rates and thresholds may vary over time, according to customer characteristics (property value or income) or location. Two-part, rising block and declining block tariffs are widespread. The two former types are gaining ground due to a general shift of opinion away from consideration of water supply as a public service to its use as a commodity with a correct price. Seasonal tariffs (summer/winter) are uncommon, but are becoming more widespread. Peak tariffs (hourly or daily) have only been tested in experiments.

Examples of pricing methods for irrigation

Cyprus: Water for irrigation purposes is supplied through government and non-government schemes. Irrigation water in government schemes is delivered directly to individual farmers (retail supplies) and in isolated cases is also provided on a bulk basis to irrigation divisions. Non – government schemes consist of small irrigation schemes, which are managed by committees chaired by the District Officer. For irrigation provision through the government schemes, charges are established on a volumetric basis and are uniform for all schemes covering a high proportion of the total financial cost.

France: Irrigation water is commonly priced by a two-part tariff method, which consists of a combination of a volumetric and a flat rate. In 1970, the Société du Canal de Provence et d'Aménagement de la Région Provencale, which supplies 60000 ha of farmland and nearly 120 communes, introduced a pricing scheme in which rates vary between peak demand and off-peak periods. The peak period rate is set to cover long-run capital and operating costs. The off-peak rate is set to cover only the operating costs of water delivery. About 50 % of total supply costs (variable and fixed) are subsidized by the State (OECD, 1987).

Greece: Per area charges are common. The proceeds usually cover only the administrative costs of the irrigation network. The irrigation projects are categorized as of basic, local and private importance and the project areas are also classified as areas of national, public or private interest. The proportions of the capital costs of an irrigation project paid by farmers are 30, 50, and 40 % for projects classified as of national, public and private interest, respectively (Gole et al., 1977).

Spain: The water charges are established per agricultural area and not per volume consumed. This means that the user pays the same amount despite the amount of water used and there is no real incentive for saving water (MMA, 1998).

Tariffs may be designed with several aims, which may in some cases be in conflict:

- efficiency (maximum net benefit for society)
- raising revenue to cover the costs of supply in a fair and equitable way
- reducing environmental costs (abstraction and pollution)
- understandable for customers and applicable for administration purposes

In fact, improving the fairness or efficiency of a tariff often makes it more complex and more difficult to understand.

Economic incentives (water charges and taxes) have mainly been introduced with the aim of generating revenue to partially cover the cost of supplies.

Maximum economic efficiency is attained when the price is set at the level where marginal costs equal marginal benefits. Volumetric pricing is a mechanism through which tariffs can be designed to achieve efficiency and to account for equity (access of the poor) without involving high transaction costs due to monitoring, measuring and collecting water charges. The effectiveness of direct water charges on volumetric basis in changing the users' behaviour will mainly depend on the price elasticity of demand. Pricing of water can also reflect the quality of water. The higher the amount used, the higher the price per unit. Users, both residential and agricultural, will adjust their use behaviour to the structure of the tariff, and respond by improving their water use practices. One caveat is that in many countries, and especially in the case of irrigation water, the effectiveness of price increase is affected by the difference between the value of unit of water to the user (the shadow price of water) and the actual price charged per unit of water. In many countries, that difference is so big that for any price increase to be effective it has to be so high, that political considerations may arise that will prohibit it from happening.

Irrigation water can also be priced on the basis of output per area, i.e. irrigators pay a certain water fee for each unit of output they produce. The basic concept is that farmers should pay the charge according to the crop productivity or the value of output, or the marginal value product of water per unit of water used.

Subsidies can be provided either directly to users of water or for a water use technology. The adoption of subsidy measures for promoting efficient water use is often practiced for promoting environmentally friendly technologies, but it is also used to promote water savings, from which society as a whole may benefit. Different types of subsidies such as grants or payments to farmers, budgetary subsidies (e.g. tax credits), provision of extension services, preference loans, debt relief, etc, could be implemented depending on their effectiveness and suitability to a particular country.

Tax incentives are designed to modify behaviour by encouraging particular groups or activities, and could be implemented in the form of preferential tax treatment to certain producers or residential consumers through tax credits, exemption or deductions, or through tax benefits provided to investors. Taxes are relevant in the case of negative externalities resulting from water use. For example, the excess pumping of groundwater lowers the water table, increases salinity of the aquifer and creates negative regional externalities. The excess withdrawal of water also results in degradation of ecosystems because the minimum water requirement of the ecosystem is not met due to the lowering of the water table and the reduction of the regional water balance. A tax incentive, equal to the marginal environmental damage cost, could be designed and implemented so that the water charge also addresses these ecological concerns. Indirectly, environmental taxes can also be imposed on the water-related inputs such as energy inputs and chemical fertilizers, which also partly influence the level of water use and the level of externality. Energy usually used in water abstraction is highly subsidized and encourages farmers to use more water at a relatively lower cost of extraction (Tiwari and Dinar A., 2001). Such taxes can be designed so that individuals internalize the externalities by improving water use efficiency and gradually adopt efficiency measures.

Water banks and markets

Water banks or markets are mechanisms to sell or rent water use rights. They exist in the USA, Chile, Canada and Australia. In Europe, water banks are a new concept and the only fully developed experience is the one of the Canary Islands in Spain (Aguilera-Klink et al., 2000). In order to tackle water scarcity problems, the Spanish government is currently implementing "Centers for the Exchange of Water Rights" in the Segura, Júcar and Guadiana river basins and developing legal regulations for water banks.

Water bank regulations have to ensure a difficult balance that stimulates the exchange of water rights and, at the same time, protects the environment and every water user.

Water banks offer several opportunities to tackle drought problems: as water user acquires a "value", current water users save water in order to sell their rights on the unused amount of water. At the same time, new water users (e.g. tourism) in water stressed areas with limited water permit to have a legal way of acquiring water rights and would not illegally abstract it. Water banks can furthermore support the establishment of environmental stream flows in certain river stretches, either by establishing a percentage of sold water for environmental purposes or by acquiring water rights. This measure can directly support the establishment of a good ecological status, as requested by WFD.

However, water banks have some inherent risks:

- Upstream concentration of water rights can reduce stream flows in river stretches.
- Changes in water use can produce higher pollution.
- In water stressed areas, "virtual" water[18] might be sold because legally established water rights might exceed the existing resources.
- If a public water bank does not work adequately, a "black" water market might appear.

For all these reasons, it seems appropriate to introduce water banks in a step-by-step approach, avoiding illegal water sellings and fixing a baseline water price that ensures that resource and environmental costs are taken into account.

Social approach

Users education and information

Dialogue with users and participation of citizens is essential for an efficient water management, permitting a demand regulation and a better use of amenities. Information and educational campaigns in all sectors are always part of a wider plan to use water more efficiently by encouraging more rational water use and changing habits. For this purpose, public awareness has to be motivated. As a user, the citizen gives financial support (taxes) to mobilize and distribute the resource as well as rectifying quality and quantity variations. Civic pressure has to be as constructive as possible, so it is necessary to inform people about roles and means of water managers. Information campaigns as well as promoting water-saving devices, raising prices to pay for leakages, are important initiatives.

In the agricultural sector for instance, farmers must be helped to optimize irrigation by means of training (on irrigation techniques), regular information on climatic conditions, adaptation of the irrigation volume and period according to the type of crop, rainfall level and type of soil.

In the industrial sector, water savings are just part of a wider programme which includes measures to reduce water pollution and implement environmental management systems.

It is difficult to quantify the effect of a public educational campaign because it is always part of a wider water-saving programme which includes other measures.

[18] Here virtual water does not refer to the water used in the production of a good or service, as introduced by T. Allan, 2003

Institutional aspects: conflict resolution and administrative settings

The administrative setting of river basin authorities is a key factor to adequately implement drought mitigation measures, especially those regarding law enforcement. Two recent NGO reports (WWF, 2003a ; WWF and EEB, 2005) show that administrative setting of competent authorities for water management and implementation of the WFD are still a pending issue in many EU countries.

“Unpopularity” or concern for social consequences of drastic alleviating measures such as the closure of illegal boreholes, make their practical application very rare. This fact does not help respect the corresponding law and also explains why, for example, the Guadalquivir river basin authority (Spain) waited 18 years to start mapping illegal boreholes in the Doñana National Park, finding 100 % of completely or partially illegal water users in the first studies (CHG, 2003).

Lack of incentives to comply with the law is also due to the fact that suiting infringements through administrative and legal procedures takes years and frauds can even expire before the suiting process is completed.

In other cases, the existing legislative text is the result of a long negotiation which has weakened and altered the original objective of the law. For instance, the Spanish 1985 Water Act converted water from private to public good, with the objective of improving the manageability of this resource. However, during the negotiation of the legislative text, it was decided to maintain property rights for all those that could prove to be water users before the entrance into force of the act. This has caused a huge administrative overload. 20 years after, the filing of all the application forms for the recognition of private rights is still unfinished. Frauds still exist, for example in the hydrogeological unit 04.04 of the Guadiana river basin, the water volume associated to registered rights currently doubles the unit renewable water resources. It becomes practically impossible for some river basin authorities to manage this public good. In the Alicante province, on the Mediterranean coast, almost 80 % of water rights are private.

A part of these shortcomings is due to a lack of human resources in water administration, both in terms of staff number technical competences needed to deal with increasingly complex legal requirements. Water policy actions should strengthen river basin authorities' role and the capacity to enforce the existing law. Moreover, the speeding up of judicial procedures against frauds would help making the river basin authorities’ control action more effective than it is for the moment.

Wider user participation

To keep a permanent dialogue, the user must be associated to the decision process and participate at the most upstream level as possible to the different steps of the establishment of fixtures. The adaptation of fittings to the demand is the condition for their acceptance by the public.

The place given to users in water management has been increasing with the passing of years. Water services are developed for users but they have only been beneficiaries of those services for a long time. Their places have gradually been recognized by the mean of organisations such as consultative commissions of local public services where users are represented and can officially share their positions.

A lot of associations have developed in water sector. Many of them deal with environmental protection. They provide information to the public, education, actions in law, environmental maintenance and management of specific systems. Recently, a new type of (often local) associations is developing in water services management and sanitation (management modes, price of water, etc) in connexion with specialized consumers’ associations.

In France, a particular water services management have been developed: delegation of services. A city gives to an enterprise (after a call for tender) the service exploitation and eventually the investments charge. They are linked by a contract. Since the middle of the

19th century, this device has permitted the development of big industrial groups, or to smaller groups have risen these last years, often at a regional scale.

Education and awareness campaigns

The financing of educational and sensitisation campaigns must not be considered as a brake for action but as a tool for promotion and profitability of this action. The message has to be adapted to specific publics according to their interests. The size of the operative organism (global or local), the width of the action zone and the level of information determine the accomplishment of the actions vis-à-vis users and beneficiaries of a given project. A big organism will provide information at a large scale about comprehension of the water cycle, the fragility of the resource and the impact of the problems on health and daily life. This kind of information sets general public's sight. A local operator, directly concerned by a specific project in a reduced perimeter of action, will explain the advantage of the project to the users, the correct and efficient utilization and the importance of maintaining this fixture. The users targeted are the direct users and beneficiaries of the installation.

Useful information has to be selected in order to sensitize users and point their behaviour toward a better use of water and get their endorsement for the projects they are concerned with. The information providers must be aware of the needs and demands of the target public (as well as his link with water) and use the field knowledge in order to be more efficient.

Dialogue and participation of the users can be achieved by two means:

- Meetings of different users categories and beneficiaries as well as their representatives
- Moderators visiting users for a more direct and individual contact

Conclusion: integrated water management approaches on demand side measures

The management of water is very different across Europe and on the Mediterranean area. A range of regional and decentralized policies already exists. The WFD is an important step towards integrated management of water resources at a river basin scale and towards harmonisation of water policies among member states. These integrated water management approaches and the tools of the WFD could be used for Mediterranean non EU countries in order to facilitate a better management of the demand side in these countries.

3.2.2. Supply-side measures

Natural catchment storage

Water naturally stored in catchments as lakes, rivers, aquifers and wetlands is globally abundant in Europe with seasonal and regional variability.

Wetlands are usually considered as patches in catchments, isolated from other functional elements. Hydrologically speaking, wetlands are discharge areas with many economic, social, natural, environmental values and services as a source of drinking water, water for irrigation, fishing, wildlife, biodiversity, etc. However, wetlands can behave like recharge areas to aquifers in many parts of the world, generally in arid and semiarid zones. Streambeds in the catchments and floodplains usually recharge aquifers during periods of floods or when high discharges occur. It is especially important in arid and semiarid areas where rainfalls are usually scarce and successions of dry years are unpredictable.

Although the relationship between groundwater and wetlands is very complicated and not well known, it is accepted that aquifers are the best manner to store water in these semiarid regions where evapotranspiration exceeds the rainfalls and water deficit may be significant during many months along the year. Moreover, storage water in aquifers decreases seasonally following the characteristic natural variability of water resources in arid and semiarid regions, not suffering from drought impacts as dams do. Some aspects regarding

the role of wetlands in the water cycle at river basin scale are tackled in the CIS Guidance Document N°12 "The role of wetlands in the Water Framework Directive".[19]
Some experiences show us the importance of good management of natural storage water in catchments during drought periods. For example, in Messana Valley in Crete, about 50 % of recharge to the aquifer occur through catchments streambeds. During a wet year, the aquifer can store 19 million m3 of water. Each year, about 22 million m3 are withdrawn to irrigate olive trees and vines. In southeast of Spain, an alluvial aquifer (Sinclinal de Calasparra) is used during drought periods to supply drinking water to 76 Segura river basin villages. Sebkhet Kelbia, located in central Tunisia, is a big flood-plain wetlands of 1 300 ha and one of the 16 Natural Reserves of Tunisia, designated for strict nature protection. It receives water from three rivers (Nebhana, Merguellil and Zeroud) that rise in the near mountains. During floods, these rivers recharge alluvial aquifers although outside this period the rivers are dry. Water from aquifer is then used for irrigation.
The ecological integrity of wetlands maintenance, especially for those located in arid and semiarid regions, is not a simple technical question, but increases the supply of groundwater that may be essential for many human activities survival during drought years.

Aquifer recharge

Natural aquifer recharge (from rain or surface water infiltration) is vital in order to maintain the groundwater and to replenish the discharges from the aquifer with a good quality water resource, but in many cases is quite impossible to grant a sustainable groundwater level only considering natural recharge.
In many areas of the world, aquifers that supply drinking-water are being used faster than they recharge. Not only does this represent a water supply problem, it may also have serious health implications. Moreover, in coastal areas, aquifers containing potable water can become contaminated with saline water if water is withdrawn faster than it can naturally be replaced. The increasing salinity makes the water unfit for drinking and often also renders it unfit for irrigation.
To remedy these problems, some authorities have chosen to recharge aquifers artificially with treated wastewater, using either infiltration or injection. Aquifers may also be passively recharged (intentionally or unintentionally) by septic tanks, wastewater applied to irrigation and other means.
Artificial recharge is the planned, human activity of augmenting the amount of groundwater available through works designed to increase the natural replenishment or percolation of surface waters into the groundwater aquifers, resulting in a corresponding increase in the amount of groundwater available for abstraction. Before deciding on aquifer recharge as a measure to solve water scarcity problems, an analysis needs to be undertaken to ascertain if and how it would affect other water bodies, such as surface, transitional or coastal waters. Aquifer recharge cannot be made without an understanding of the whole water cycle. Furthermore, before aquifer recharge, it is necessary to identify the water services that would benefit from this measure and how and in which proportion they would be required to recover the costs of the measure. In this sense, artificial aquifer recharge must be considered as part of a wider approach to water resource management which addresses demand and quality issues as well as supply aspects. Although the primary objective of this technology is to preserve or enhance groundwater resources, artificial recharge has been used for many other beneficial purposes. Some of these purposes include conservation or disposal of floodwaters, control of saltwater intrusion, storage of water to reduce pumping and piping costs, temporary regulation of groundwater abstraction, and water quality improvement by removal of suspended solids by filtration through the ground or by dilution

[19] See document on CIRCA: http://circa.europa.eu/Public/irc/env/wfd/library?l=/framework_directive/guidance_documents&vm=detailed&sb=Title

by mixing with naturally-occurring groundwaters (Asano, 1985). Artificial recharge also has application in wastewater disposal, waste treatment, secondary oil recovery, prevention of land subsidence, storage of freshwater within saline aquifers, crop development, and streamflow augmentation (Oaksford, 1985).

Aquifer recharge with treated wastewater is likely to increase in future because it can:

- restore depleted groundwater levels
- provide a barrier to saline intrusion in coastal zones
- facilitate water storage during times of high water availability.

If aquifer recharge is haphazard or poorly planned, chemical or microbial contaminants in the water could harm the health of consumers, particularly when reclaimed water is being used. Wastewater may contain numerous contaminants (many of them poorly characterized) that could have health implications if introduced to drinking-water sources. Ensuring that the use of treated wastewater for aquifer recharge does not result in adverse health effects, a systematic science-based approach is needed, designed around critical control points, as used in the hazard analysis critical control point (HACCP) approach. Such an approach to potable aquifer recharge requires a thorough evaluation of the best practices that will protect public health, and consideration of environmental and sociocultural concerns.

A variety of methods have been developed and applied to artificially recharge groundwater reservoirs in various parts of the world. The methods may be generally classified in the following four categories (Oaksford, 1985):

- Direct Surface Recharge Technique (Asano, 1985).
- Direct Subsurface Recharge Technique.
- Combination surface-subsurface methods, including subsurface drainage (collectors with wells), basins with pits, shafts, and wells.
- Indirect Recharge Techniques.

Direct surface recharge techniques are among the simplest and most widely applied methods. In this method, water moves from the land surface to the aquifer by means of percolation through the soil. Most of the existing large scale artificial recharge schemes in western countries make use of this technique which typically employs infiltration basins to enhance the natural percolation of water into the subsurface. Field studies of spreading techniques have shown that, of the many factors governing the amount of water that will enter the aquifer, the area of recharge and length of time that water is in contact with soil are the most important (Todd, 1980). In general, these methods have relatively low construction costs and are easy to operate and maintain. Direct subsurface recharge techniques convey water directly into an aquifer. In all the methods of subsurface recharge, the quality of the recharged water is of primary concern. Recharged water enters the aquifer without the filtration and oxidation that occurs when water percolates naturally through the unsaturated zone.

Direct subsurface recharge methods access deeper aquifers and require less land than the direct surface recharge methods, but are more expensive to construct and maintain. Recharge wells, commonly called injection wells, are generally used to replenish groundwater when aquifers are deep and separated from the land surface by materials of low permeability. All the subsurface methods are susceptible to clogging by suspended solids, biological activity or chemical impurities.

Combinations of several direct surface and subsurface techniques can be used in conjunction with one another to meet specific recharge needs.

Indirect methods of artificial recharge include the installation of groundwater pumping facilities or infiltration galleries near hydraulically-connected surface waterbodies (such as streams or lakes) to lower groundwater levels and induce infiltration elsewhere in the drainage basin, and modification of aquifers or construction of new aquifers to enhance or create groundwater reserves. The effectiveness of the former, induced recharge method depends upon the number and proximity of surface waterbodies, the hydraulic conductivity of the aquifer, the area and permeability of the streambed or lake bottom, and the hydraulic gradient created by pumping. Using the latter technique, aquifers can be modified by structures that impede groundwater outflow or that create additional storage capacity. Indirect methods generally provide less control over the quantity and quality of the water than do the direct methods.

For example, Managed Aquifer Recharge (MAR) is a method of adding a water source such as recycled water to underground aquifers under controlled conditions using infiltration galleries. Treated effluent flows via an inflow pipe, then flows down through a chamber into covered galleries (engineered trenches that facilitate the infiltration of water into the ground and consisting of parallel slotted pipes containing either gravel or open plastic structures). The top and sides of the galleries are covered in geotextile material to prevent topsoil from entering the galleries, while the base is open to the in situ soil. The trenches are about 10 metres above the water table to allow water quality improvements to occur in the in situ soil before recharging the aquifer. As the treated water infiltrates the soil natural biological, chemical and physical processes occur to remove pathogens, chemicals and nutrients from the water. This "filtering" process continues whilst the water infiltrates and resides in the aquifer. The following water quality improvements occur during the process: removal of nutrients such as phosphates and organics, degradation of chemicals such as disinfection by-products, pathogen die-off. This significantly reduces the health and environmental risks that may be associated with secondary treated wastewater, leaving the reclaimed water in similar quality to that of the surrounding groundwater. This method costs less to treat and use reclaimed water using MAR than desalination ; however should high quality water be required the reclaimed water may still need to be desalinated. As there is much less salt in reclaimed water than seawater, significantly less energy is required to desalinate reclaimed water[20].

Dams

Reservoirs play an important role in public water supply, irrigation and industrial uses. The construction of dams, however, can have serious implications for the functioning of freshwater ecosystems in a river basin and ultimately impact livelihoods.

Dams disconnect rivers from their floodplains and wetlands and reduce river flows. They act on the migratory patterns of fish and flood riparian habitats, such as waterfalls, rapids, riverbanks and wetlands, which are essential feeding and breeding areas for many aquatic and terrestrial species. Dams also disrupt the ecosystem services provided by rivers and wetlands, such as water purification. By slowing the movement of water, dams prevent from natural downstream movement of sediments to deltas, estuaries, flooded forests, wetlands, and inland seas, affecting species composition and productivity.

The World Commission on Dams found that the technical and economic performance of many water supply dams, both irrigation and bulk water supply, have failed to reach the intended targets. The survey showed that, except 29 dams with a water supply component (excluding irrigation), 70 % of dams did not reach their targets over time, and a quarter of dams delivered less than 50 % of the target. Equally, irrigation components of large dams studied by the WCD fell short on targets, including the areas irrigated. However, dams with heights inferior to 30 m and reservoirs of less than 10 km^2 tended to be closer to predicted targets (World Commission on Dams, 2000).

When considering dams as a structural solution to water scarcity, the decision making process must be realistic about the dam technical and economic performance, as well as about the environmental and economic cost associated to the disturbance and loss of ecosystems and the services they provide.

[20] See the following websites: http://www.who.int/water_sanitation_health/wastewater/; http://www.csiro.au/files/files/p2oq.pdf; http://www.unep.or.jp/ietc/publications/techpublications/techpub-8e/artificial.asp

The construction of new water supply dams and the management of existing dams in Europe are subject to EU legislation, especially WFD, which aims to ensure the environmental quality of water bodies. The directive applies to all surface waters (rivers, lakes and coastal waters) and groundwater in a river basin. Its objective is to achieve at least a "good ecological and chemical status" of all waters by 2015, as well as preventing from the deterioration of current status. Volume of water flow is included in the definition of ecological status. This is of particular relevance to dams which tend to interrupt stream flow. This has implications on new dams construction, which inevitably modify water bodies status. According to article 4-7 derogation provision, WFD allows the development of new water infrastructure, even if it prevents from reaching good status. However, this provision comes with a number of strict conditions, including:

- conditions for mitigation measures
- proof that there are no better alternative options in environmental terms
- condition that the project is either of "overriding public interest" or that the provision of benefits to human health and safety (e.g. flood control) or sustainable development outweight the benefits of achieving the directive environmental objectives. Furthermore, articles 4.8 and 4.9 are mandatory as conditions for these derogations.

WFD implications for existing dams depend on whether or not the water body is classified as heavily modified, fulfilling article 4.3 criteria and respecting those of articles 4.8 and 4.9. In other cases, dam sites may be subject to extensive mitigation measures implementation in order to reach good ecological potential, particularly regarding minimum flow regimes, aquatic fauna migration and sediment management. In addition, the fact that these water bodies also need to reach good chemical status should be taken into account (Barreira, 2004).

Use of basin-external water resources

Alternative sources

<u>Desalination</u>

This technique is used when technically and economically feasible. There are more than 7500 desalting plants in operation worldwide producing several billion gallons of water per day. 57 % are in the Middle East and 12 % of the world capacity is produced in the Americas, with most of the plants located in the Caribbean and Florida regions. However, as drought conditions continue and concerns over water availability increase, desalinization projects are being proposed at numerous locations.

A number of technologies have been developed for desalinization which include distillation, reverse osmosis, electrodialysis, and vacuum freezing. Two of these technologies, distillation and reverse osmosis, are being considered by municipalities, water districts and private companies for the development of sea water desalinization.

Desalinization costs are very sensitive to the salinity of the feed water. Desalinization of brackish waters and waters that are mildly saline can be economically justified for some high valued uses. Seawater desalinization remains enormously expensive when all costs are fairly accounted for. There is a tendency to promote seawater conversion projects that are joint with power plants. The resulting costs are almost always understated because the power is subsidized and all of the joint costs are allocated to power production. Seawater conversion is unlikely to be the solution to water problems except in a few instances where there are no alternative sources of supply and there is considerable wealth to defray the costs of seawater desalinization (Vaux H. Jr., 2004).

Water treatment costs vary by the amount of salt removal, cost of energy, size of plant, as well as the type of treatment technology. Desalinization costs are dominated by capital investment, energy and maintenance costs. Reverse osmosis systems, which utilize membrane technology for water treatment, have the lowest cost of operations, especially in areas with high power cost. While membrane technology advances have resulted in significant cost reductions, energy still accounts for up to 60 % of the operating cost. Further improvements in energy efficiency will deliver sustainable reductions in operating cost. Along with improvements in energy efficiency, improvements in membrane performance and membrane life through integrated treatment systems can reduce capital cost and life cycle cost. Membrane-based treatment solutions are essential to create new water sources such as brackish water aquifers, seawater, and even wastewater. Membrane-based desalinization and reuse is a proven solution, but a broader application of these technologies to create meaningful new water sources requires investment to further reduce the energy consumption associated to the operation of membrane systems. The long-term, sustainable solution to produce economical sources of new water lies in developing more advanced, energy-efficient technologies to treat multiple water sources. As a practical matter, substantial incremental funding for research and development would significantly accelerate the development of economical sources of new water[21].

Rain Water Harvesting

To help meet water demand, rainwater harvesting and grey water practices are commonly used in several European countries. Traditional regulatory practices prohibiting rainwater harvesting or grey water reuse as substitutes for potable water supply are changing. Applications of these practices are supported by commercially available technologies. Where these practices and technologies are encouraged by regulations, they are increasingly being used. The incentive may be a lack of alternative water supply, or where available water is not an issue, the cost of publicly supplied water may be encouraging acceptance[22].

Rainwater harvesting involves the use of captured rainwater, usually from a roof catchment, which otherwise would have soaked into the ground, evaporated or entered the drainage system. Once captured, the water can be drawn on for a variety of uses from irrigating crops or gardens, as toilet flush water, in water features and occasionally as a source of drinking water. Watering a garden with rainwater collected in a water butt is a rudimentary form of rainwater harvesting.

Where there is negligible potential human contact, the rainwater will usually only require coarse filtration to prevent leaf litter, debris and small animals entering the system. If the rainwater is to provide a potable water supply, thorough treatment is required, which makes this use uncommon.

During rainfall events, the first flush of water usually has the lowest water quality due to contamination from leaf litter, bird droppings and wind-blown pollutants that have adhered to the roof surface or guttering. For this reason, many rainwater harvesting systems divert the first flush of water so that it is not used.

The amount of rainwater that can be harvested is a function of the rainfall received and plan roof area. For example, in Northern Ireland, where 2004 annual rainfalls were just over 1000 mm/year, a home with a 100m2 plan roof area could harvest 60 m3 of rainwater, assuming that 60 % of rain that falls on a roof catchment is collected and used.

Legislation in France permits the use of rainwater for certain purposes and under certain conditions. Untreated, the water can only be used for external utilisations such as irrigation and automobile washing, or where there is suitable plumbing construction preventing cross-contamination or cross-connexions, it can be used inside homes for toilet flushing. A number of experimental buildings that incorporate rainwater harvesting systems have been constructed in France. Studies have unequivocally demonstrated that such systems can be

[21] See website: http://energy.senate.gov/public/index.cfm?FuseAction=Hearings.Testimony&Hearing_ID=1508&Witness_ID=4289

[22] See website: http://www.cmhc-schl.gc.ca/publications/en/rh-pr/tech/03-100-e.htm

designed, constructed and implemented with due regard to public and environmental health. It is claimed that an average residential rainwater harvesting system can be fully amortized in less than three years.

National legislation in Belgium requires all new constructions to have rainwater harvesting systems for the purposes of flushing toilets and external water uses. The aim of this legislation is twofold: 1) to reduce demand for treated water and the expansion of the water supply infrastructure; and 2) to collect and use rainwater instead of surcharging stormwater management systems.

Domestic Grey Water Reuse

Conventional toilet flush water is supplied water unnecessarily treated to drinking water quality standard, an expensive and energy intensive process. Greywater recycling is an innovative alternative whereby treated greywater is principally used for toilet flushing but also for gardens watering. Greywater is wastewater from showers, baths, wash basins, washing machines and kitchen sinks although for recycling purposes kitchen sink and washing machine water is normally excluded because it is too greasy and/or contains too many detergents to allow cost effective treatment.

Unlike rainwater, greywater requires filtration to remove hair, skin and soap products from the water and chemical or biological treatment prior to reuse. The potential level of human contact with the water in its end use will determine what level of treatment is required. For example, greywater used for hosing down vehicles will require a high water quality because the risk of human contact with the water is greater in highly pressurized systems. Similarly, black water (toilet effluent diluted by flushing water) is not recycled because of the even higher level of treatment needed before it is safe for human contact. Public acceptance is also a major barrier here.

Perhaps the two biggest barriers to widespread uptake of greywater recycling are public concern about the risk to health and system maintenance requirements. The health concerns are twofold: firstly the health risk from contact with greywater in the normal operation of the system and secondly the health risk posed by the breakdown or ineffective operation of the treatment system. Greywater recycling systems are designed for minimal user contact with the greywater. Aerosols from toilet flushing are the only potential contact most users will have with the water and this is unlikely to have health implications if the water has been properly treated. It can be minimized even further by closing the toilet lid prior to flushing.

There is a health risk however where treatment systems have broken down or not been maintained correctly so that untreated water (which may have been stored for long periods) comes into contact with users. Where untreated greywater has a long residence time in the system, the risk is greater. If there are pathogens such as enteric viruses, giardia, cryptosporidium, salmonella and campylobacter present in the wastewater from affected individuals, lengthy periods of poor storage could result in the water turning septic and posing a health risk. The untreated greywater awaiting treatment should instead be stored in a dark, cool container and continually stirred to prevent anaerobic conditions. Despite these risks, there are numerous safeguards which together diminish the health risks almost completely:

- Ultraviolet, chemical and/or biological disinfection
- Periodic inspection and cleaning of the system to ensure the water is being adequately disinfected
- Clear identification of pipes which are carrying greywater and incompatibility with main pipework
- Pale colouring added to the recycled water to differentiate it from potable water
- User training covering how the system works and good practice to adopt to minimise potential risks

- A manual “divert” option whereby excessively contaminated water does not have to enter the recycling system
- Multi-occupancy buildings are likely to have greater water circulation ensuring the greywater used is fresh rather than having had a long storage residence time in the system.

Use of alternative water resources in Industrial cycle

Industry is one of the largest consumers of water. Water is used for processes as diverse as mixing, cooling, boiler feed and plant wash-down as well as for washrooms and other sanitary uses.

Unlike most residential properties, industry and business in the UK are subject to compulsory metering. With the cost of mains water, sewerage and trade effluent rising, businesses are increasingly conscious of the substantial water, and therefore cost, savings that water reuse and water conservation can achieve. For example the five finalists in the Industry category of the 2005 Water Efficiency Awards were able to cut water consumption by between 25 and 98 % by adopting a combination of water reuse and conservation strategies. Enhanced Capital Allowances, a UK Government initiative, promotes this sustainable solution and provides tax incentives for water saving and rainwater devices and water reuse with membranes as well from September 2005[23]. In addition to these water cost savings other potential benefits to industry include[24]:

- avoiding water restrictions imposed during periods of drought
- reduced energy and chemical costs through recycling
- removing the need for discharge consents
- good publicity opportunity
- improved company image and reputation amongst the public, customers and own workforce
- helping to achieve certified environmental accreditation (e.g. ISO 14001)
- fulfilling corporate social responsibility commitments

Sustainable Drainage Systems

Sustainable Drainage Systems (SUDS) is an approach to drainage which seeks to decrease the amount of surface runoff, decrease the velocity of surface runoff, or divert it for other useful purposes, thereby reducing the contribution it makes to sewer discharge and flooding. As well as controlling the quantity of runoff, SUDS can also improve the quality of runoff, preventing pollutants from entering the drainage system. SUDS will also “green” the urban environment and should provide landscape, amenity and biodiversity benefits too.
Techniques that come under the SUDS umbrella vary enormously but usually involve some of the following components :

- Permeable and porous surfaces to reduce surface runoff
- Ponds/basins for temporary storage during high magnitude rainfall events (detention basins) or longer term storage (retention basins)
- Pipes and channels to divert water from undesirable locations
- Structures that increase the lag between a rainfall event and discharge of water to the drainage system by increasing infiltration.

The SUDS approach is particularly valuable in urban areas where high density development and impermeable surfaces mean surface runoff can easily cause flooding, either directly or indirectly through sewer flooding[25].

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[23] See website: http://www.eca-water.gov.uk/
[24] See website: http://www.ciwem.org/resources/water/industrial/
[25] See website: http://www.ciwem.org/resources/water/suds/

Direct and Indirect potable reuse

Direct potable reuse (i.e. treated wastewater directly reused for drinking water) is very rare because of the increased potential risk to public health and the negative public perception. Even though the technology is well proven, direct potable reuse is only justifiable when there is no other option for example in the desert or outer space. Currently, the only place where direct potable reuse takes place on a municipal scale is in Windhoek, Namibia where treated wastewater combined with surface runoff is treated to provide potable water. Direct reuse is common practice for non potable applications in industry and irrigation.

Indirect potable reuse can be planned or unplanned. Conventional water treatment in many countries involves unplanned indirect potable reuse of treated wastewater. Water abstracted from rivers to provide drinking water includes treated wastewater that has been discharged upstream. It is unplanned in the sense that it is not an intentional part of the wastewater discharge policy that the water will be reused downstream for potable water supply. The abstracted water will still need to meet potable water standards if it is to supply drinking water. River water may go through several abstraction/treatment/use/treatment/discharge cycles before reaching the sea. The pursuit of economies of scale has led to a tendency for large down-catchment wastewater treatment plants. Planned use by relocating treatment and shortening the use/reuse cycle could increase water availability for both environmental and other purposes.

The reason why indirect water reuse is not considered to pose a health risk is that the treated wastewater benefits from natural treatment from storage in surface water and aquifers and is diluted with "ordinary" river/ground water before abstraction to ensure good drinking water quality (part of a multi-barrier approach in the water safety plan). The storage time provides a valuable buffer to measure and control quality. Direct potable reuse, however, is almost a closed loop system with limited storage and a shorter buffer time therefore increasing the risk[26].

Use of alternative water resources for Irrigation

Irrigation is the artificial application of water to the ground surface in addition to what falls naturally as rainfall. Unlike energy production that gives back the majority of the removed water to the environment, irrigation consumes half the water deducted from the environment because of absorption and evapotranspiration[27].

Since the mid-1990's, irrigation has consistently been the largest use for freshwater globally. In France, a 66 % increase of the irrigated surface has been observed between 1988 and 1997. The use of recycled water for irrigation is widespread because water quality standards are less stringent where water is not for potable use or direct human contact. Irrigating land uses extensive amounts of water so there may be cost savings associated to using recycled water too. The two main irrigated environments are agricultural land (horticulture, crop production and grazing pasture for livestock) and amenity/recreation areas (e.g. golf courses, public parks, and commercial landscaped gardens). The quality of water required for irrigation of agricultural land will depend on the crop type and whether the crop is eaten raw or cooked[28].

Increasing availability of water resources

The creation of new resources is rarely a sustainable solution for environmental management, considering the heavy cost and the impact on natural systems. But the creation of a new resource, when ecologically feasible and within rational economic conditions, is conceivable, when the imbalance is so great that other imaginable management measures

[26] See website: http://www.ciwem.org/resources/water/potable/
[27] See website: http://www.ifen.fr/publications/DE/PDF/de104.pdf
[28] See website: http://www.ciwem.org/resources/water/irrigation/

seem to be insufficient. But this approach mustn't become an escape ahead. For that reason, withdrawals have to be stabilized in order to keep the advantage of the resource creation in terms of restoration, because an increase can contribute to the imbalance. For this purpose, collective commitments for withdrawals limitation have to be made, leading to results with the height of the stakes, by the mean of existing collective structures or creating organisms that gather the concerned irrigators when they do not exist.

Nevertheless and generally, the cost in capital of collective infrastructures for storage and transfer is not affordable for the majority of the irrigators. These collective infrastructures have mostly been funded by public cities within development planning general policy. The WFD compels to take into account the cost recovery from beneficiaries.

Therefore, it seems important for new resources projects to be preliminary analyzed on a macroeconomic basis, so all merchant and non-merchant users can think in terms of cost/advantages and notably taking into account the perspectives evolution of water demand in agricultural sector.

In the strong imbalance zones, a solution can be seen in the creation of small water dams of substitution of which the filling is made during winter with little impact on natural systems and under the same conditions as cited before. In France for instance, the development of irrigation since the 60's has led to a correlative development of this kind of dams at a superior rate than the constitution of multi-usage and structuring resources.

The generally private status and the importance of those small dams deserve to be the object of an environmental examination. Indeed, the cumulative impact of these reservoirs at a basin scale has to be taken into account and can be equivalent or even superior to the impact of a big unique work.

Inter-basin water transfers

The main objective of inter-basin water transfer is water security. In some arid regions, this transfer is not a question of choice but a necessary act. Inter-basin water transfers are often seen as a fast and easy solution to face drought and water stress situations. Transfers require a specific derogation and justification adjusted to the criteria established in WFD articles 4.7, 4.8 and 4.9. If these criteria are met, transfers can be considered as the "last option" to address water problems. They often provoke social and political conflicts between donor and receiving basins.

In their initial planning stages, expectations towards water transfers have often been overestimated, as shown by a recent review of three different transfer projects in Spain (Tagus-Segura - WWF, 2003b- Ebro and Júcar-Vinalopó). Some particular aspects require special attention :

- water availability in donor basin, including water consumption expectations in the proper basin and variations in rainfalls and evaporation due to climate changes.
- environmental and social effects of the transfer on the donor basin.
- effects of the transfer on the receiving basin.
- costs of water transfer projects.
- respect of the derogation criteria established in WFD articles 4.7, 4.8 and 4.9.

Considering water availability, the initial Júcar-Vinalopó transfer project studies demonstrated that there were enough available resources. Nonetheless, after reviewing streamflows and environmental needs of the Júcar basin, current plans for the Vinalopó transfer consider the pumping of up to 62 Hm^3/y of groundwater from the Valencia aquifer.

Regarding the environmental effects, transfers usually worsen water bodies ecological status. For example, transfers from the Tagus basin suppose a significant reduction of stream flows in the Middle Tagus so the river currently has problems to dissolve urban and industrial pollution. Furthermore, ecological processes dynamics such as erosion/sedimentation are crucial for the maintenance of downstream ecosystems, as observed in the Ebro delta, and of the coastal waters nutritional chains (Ibáñez et al., 1999).

In receiving basins, inter-basin water transfers often promote an increased land-use and stimulate the increase of long-term water demand, as seen in the Segura basin for instance. The difference of water quality between the basins can affect freshwater ecosystems and even provoke inadequacy for potential water users, as the Ebro transfer project analysis have shown. Furthermore, aquatic species translocation is an additional risk of transfers : the Tagus-Segura transfer has transported four fish species (Carassius auratus, Gobio gobio, Chondrostoma polylepis and Rutilus arcasii) between basins and promoted hybridizing with Chondrostoma arrigonis in the Júcar basin (Oró, 2003).
The costs of water transfer projects do not often fully reflect all the transfer and associated works, infringing WFD cost recovery obligations. During the Ebro transfer project, different economic reviews of the initial studies doubled the expected price of water from 0,31€/m^3 up to 0,72€/m^3 (WWF, 2003c).
Considering the upcoming new data, the Spanish Government is currently reviewing all major transfer projects. The lessons learnt from this process should be taken into account in future projects in all countries at an early planning stage, additionally to WFD mandatory requirements, an option assessment, including non-constructive alternatives, is highly recommended.

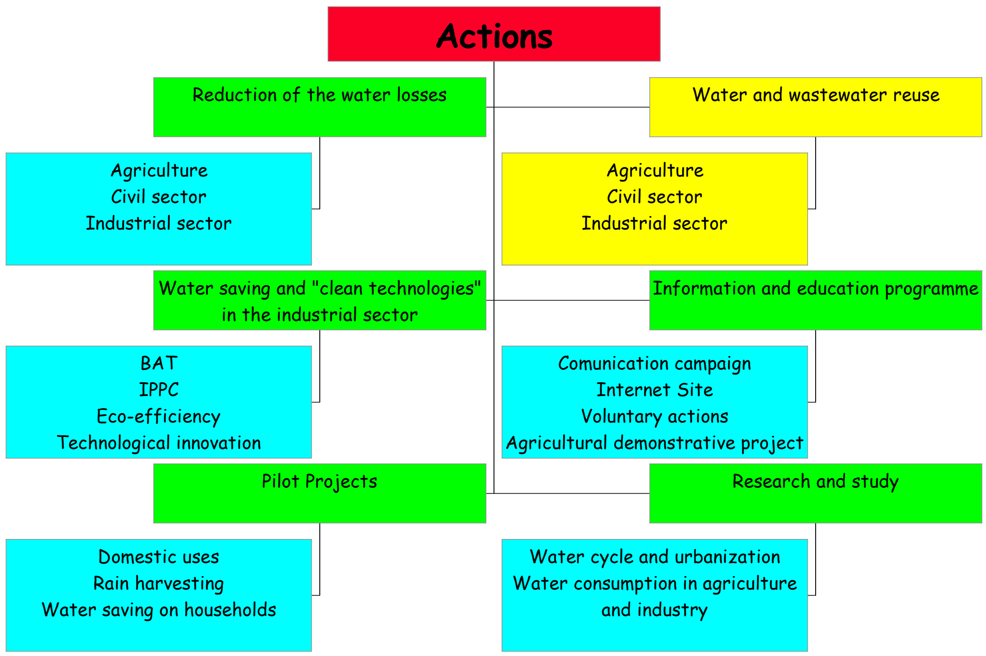
Examples of Water saving and conservation policy in Emilia-Romagna, Italy

Water Conservation and water demand management in Emilia-Romagna is a good case study to illustrate integrated water management approach. Emilia-Romagna (44° latitude) is situated in northern Italy in the valley of the Po river, bounded by Apennine Mountains to the south and the Adriatic Sea to the east. The climatic conditions of the region are related to the climatic general conditions of the Po valley (surrounded by the Alps and the Apennine) and are mostly influenced by the mountains and the sea, leading to a high spatial variability of the precipitation fields. For the region, but also for the Mediterranean zone, the water uses for irrigation are generally predominant. In December 2005, the Regional Legislative Assembly approved the Regional Water Protection Plan anticipating the WFD someway. The Water Saving and Conservation Programme is an integral part of the Water Protection Plan. The Region, together with Basin Authorities, has established the Plan objectives for each drainage basin with reference to the WFD. By 2016, every significant surface and ground water body must reach the “good” ecological quality status. In order to assure the fulfilment of this objective, each classified surface water body, or a portion of it, must acquire at least the requisites of “sufficient” status by 31st December 2008. For quantitative aspects, priority objectives are eliminating water deficit in groundwater and maintaining a minimum flow in rivers.

Water saving and conservation program

Between the 70's and 2000, there was a modest increase of the total withdrawals, with a strong replacement from the industrial uses to the irrigation uses and, partially, to the civil uses. An important decrease in the groundwater withdrawals was observed. It is also interesting to note that the civil withdrawals are stable since the 80’s. The increase in surface water withdrawals depends on the regional policies developed to answer the subsidence problems posed by the unsustainable uses of groundwater in the south-eastern part of the region, using a canal, which can take about 60 m3/sec from the Po river for agricultural uses, the Ridracoli Dam built at the end of the 80’s for civil uses and a stronger regulation of groundwater withdrawals. Nowadays the groundwater annual deficit is estimated to be around 25 Mm3/y, with the worst problems in Bologna and also in Parma. Considering the surface water, the estimated deficit due to the future application of the Minimum Flow (MF) is around 47 Mm3/y. The average regional consumption for

domestic uses is 170 L/capita/day (L/c/d). The estimated overall (real and apparent) leakage from the civil networks is 123 Mm3/y, which means about 26 % of the civil withdrawals.
The application of MF is the most demanding task. The need to keep a higher volume of water in the rivers impacts the actual use of resources with particular significance during summer when the water flow is low while the water demand is at the highest level. In most of the cases, it is needed to revise "historical" water withdrawal, that were already present in the last centuries for irrigation and old mills, and in the 20th century for drinking purposes. The level of the conflicts is therefore pretty high.
The regional strategy is based on a twin track approach and, considering the regional situation and water balance, is firstly based on the development of new regional policies for water conservation and the demand management, not forgetting the infrastructural development where necessary (for instance the local connexions with the Canal. The Conservation Program also includes a need to define a Regional Drought Contingency Programme. The main conservation actions are as shown below:



Water and energy saving

Energy production and use are responsible for the bulk of greenhouse gas emissions. Europe has committed itself in the Kyoto Protocol to reduce those emissions which come from fossil fuels burning, mainly coal, oil and gas. In its 2005 Green Paper on energy efficiency "Doing more with less", the European Commission set out a strategy to improve energy efficiency and to encourage greater use of new, renewable sources of energy. The total final energy consumption in the EU in 1997 was about 930 Mtoe. A simplified breakdown of this demand shows the importance of buildings in this context: 40,7 % of total energy demand is used in the residential and tertiary sectors, most of it for building-related energy services. Space heating is by far the largest energy end-use of households in member states (57 %), followed by water heating (25 %). The planned water savings in Emilia-Romagna will directly bring an energy saving for the domestic water heating of about 12 %, which means 3 % of all the energy needed in the residential sector (2,7 Mtoe/year in Emilia-Romagna region), which is about 1/6 of Kyoto commitment in the residential sector of the region.

Results of the regional conservation planning

The demand scenarios “business as usual” show an 8 % population growth for civil water uses, stability in the unitary consumption and a “natural” reduction of water losses (26 to 20 %). The industry is declining since the 70’s. For agriculture, irrigated surface is still growing, but technological efficiency at the field is increasing with an almost stable demand (no clear indication from CAP). With the above conservation measures and assumptions, which must lead to a reduction of domestic consumption of 170 L/capita/day (L/c/d) to 150 L/c/d by 2016, plan measures would allow, in 2016, groundwater abstraction levels essentially depending on recharge capacity, also enabling to progressively offset current piezometric anomalies. As for surface waters, critical aspects are linked to irrigation uses of Apennine waters ; plan measures will foster resource deficit reduction in view of MF application.

Regional Plan for drought management

The plan also outlines the first elements pertaining to the Regional Plan for Drought Management. The report presented by IPCC predicts changes in the regional distribution of precipitations, leading to drought and floods, changes in the occurrence frequency of climatic extreme events, particularly heat events. Climate changes that were observed during the last decades in the region seem to be consistent with the predictions and have social impacts even at a local scale. The Water Regional Plan takes care about those aspects in order to define, for the first time in the Emilia-Romagna region, a Drought Contingency Program at the regional and local scales. Studies realized for the planning, using indicators like Standard Precipitation Index (SPI), showed that the last 15-20 years were years of growing drought. Anyway this specific risk must be afforded as in other sectors (floods, etc) with a planning strategy which shall be implemented after the plan adoption and asking the local actors to define their Contingency Programs following the regional guidelines within 2006

3.3. Long-Term Imbalances Implications

3.3.1. Environmental concerns and quantitative aspects in the WFD

The WFD establishes that member states, in implementing the program of measures specified in the River Basin Management Plans (RBMP), shall protect, enhance and restore all surface water bodies and groundwater bodies with the aim of achieving good ecological status (good ecological potential for artificial and heavily modified water bodies) within 2015. Good status is defined, for surface water bodies, according to the ecological and chemical status, while, with regards to groundwaters, the good status refers to the quantitative and chemical status. So for surface waters, the Directive is more focused on qualitative aspects than on quantitative ones; nevertheless, quantitative aspects are addressed through an indirect approach.

Drought Management Plan at national level is linked to RBMP at river basin scale by the fact that there is a need of coherence between actions per basin. National strategy and instruments constitute the doctrine whereas measures are the actions at river basin level.

Moreover, RBMP must be linked to other land management plans (town-planning, public roads), especially soils management plans, in order to take into account the other management and planning instruments that can influence the quantitative management, notably in arid environments.

Integration of qualitative and quantitative aspects

Quantitative protection of water resources is closely linked to qualitative aspects. Reaching the objectives for good ecological status would be very difficult or nearly impossible without properly considering quantitative aspects. On one hand, quantitative actions are essential in order to guarantee ecosystems (typical habitats, dilution, prevention of extreme situations) and on the other hand, pollution diminishes available resources creating imbalances within the hydrological cycle and causing conditions of water stress.
With regards to the WFD compliance regime, the good quantitative status only concerns groundwater bodies.

In this sense, an integrated protection of water resources is needed to achieve good ecological status. This approach is fully taken up by the Directive which considers the key role of quantitative aspects in the recitals and especially in the following ones:

- RECITAL 19: …control of quantity is an ancillary element in securing good water quality and therefore measures on quantity, serving the objectives of ensuring good quality, should also be established.

- RECITAL 20: The quantitative status of a groundwater body may have an impact on the ecological quality of surface waters and terrestrial ecosystems associated to that groundwater body.

- RECITAL 34: For the purposes of environmental protection, there is a need for a greater integration of qualitative and quantitative aspects of both surface waters and groundwaters, taking into account the natural flow conditions of water within the hydrological cycle.

- RECITAL 41: For water quantity, overall principles should be laid down for control on abstraction and impoundment in order to ensure the environmental sustainability of the affected water systems.

Even if the above mentioned recitals clearly show the need for a greater integration of qualitative and quantitative aspects of both surface and groundwaters, the Directive does not include any specific article addressing quantitative aspects for surface waters. The quantitative status of surface waters is considered in the WFD through the inclusion of the hydrological characteristics of water bodies in the provisions for the definition of ecological status.
Regarding good status of inland water (rivers and lakes), the Directive indicates that "the hydrological regime must be consistent with the achievement of the values specified for the biological quality elements".
As mentioned above quantitative aspects are directly and fully considered in the assessment of groundwater status. A good status is achieved when the water level in the groundwater body is such that the available groundwater resource is not exceeded by the long-term annual average rate of abstraction. Accordingly, the level of groundwater is not sensible to anthropogenic alterations such as what would result from:

- failure to achieve the environmental objectives specified in article 4 for associated surface waters
- any significant diminution of the status of such waters
- any significant damage to terrestrial ecosystems which directly depend on the groundwater body

Alterations of flow direction resulting from level changes may occur temporarily or continuously in a spatially limited area, but such reversals do not cause saltwater or other intrusion and do not indicate a sustained and clearly identified anthropogenically induced trend in flow direction likely to result in such intrusions.

In conclusion, even if the WFD focuses on the qualitative aspects, it stresses that the quantitative aspects are essential for the achievement of good ecological status.
Taking into account the specificities of some aquifers in Northern Africa, compliance with the good quantitative status of groundwater would be problematic. Indeed, most major groundwater aquifers in North Africa including the Nubian Sandstone aquifer and the North Sahara Aquifer are fossil non-renewable groundwater aquifers with very limited recharge potential. In these cases, a balance between abstraction and recharge is impossible to be accomplished.

Quality and quantity in RBMP

The Directive provides some clear indications about the way to approach the need to integrate quantitative and qualitative aspects. These indications are both included in RBMP and in the program of measures.
With regards to the RBMP, the Directive sets out that they consider the water bodies' quantitative status in the river basin general characterisation and in the evaluation (table 9). Moreover, quantitative status considerations can play a role in other aspects covered by RBMP as the economic analysis or the applications of exemptions in article 4.

RIVER BASIN MANAGEMENT PLANS
River basin management plans shall comprise the following elements: 1.1 A general description of the characteristics of the river basin district which includes an identification of reference conditions for the surface water body types. 2. A summary of significant pressures and impact of human activity on the status of surface water and groundwater, including an estimation of pressures on the quantitative status of water including abstractions. 4.2 A map presentation of the results of the monitoring programmes carried out under those provisions for the status of groundwater (chemical and quantitative). 5. A list of the environmental objectives established under article 4 for surface waters, groundwaters and protected areas, including identification instances where use has been made of articles 4(4), (5), (6) and (7), and the associated information required under that Article. 6. A summary of the economic analysis of water use as required by article 5 and Annex 3. 7.4 A summary of the programme or programmes of measures adopted under article 11, including a summary of the controls on abstraction and impoundment of water, and reference to the registers and identifications of the cases where exemptions have been made under article 11(3)(e).

Table 15: River basin management plans

Quality and quantity and reference conditions

The definition of these elements, recognized by the Directive as essential for RBMP arrangements, implies the evaluation of water resource availability and the consideration of quantitative aspects in the definition of the reference conditions. For each surface water body type, the WFD requires that type-specific hydromorphological and physicochemical conditions shall be established representing the values of those elements for surface water bodies at high ecological status.

It is imperative to fully take into account quantitative aspects associated to the hydromorphological elements supporting the biological ones. In other words, in certain circumstances (e.g. arid climates, highly permeable soils, etc), quantitative aspects could play a crucial role in establishing the reference conditions and in achieving the environmental objectives.

Quality and quantity and river basin balance

The integrated quali-quantitative approach is fully coherent with the logic of the hydrological balance and the protection of a flow consistent with the GES (Good Ecological Status). The definition of a balance, in fact, requires the assessment of inflow (natural flow and anthropic discharges) and of the outflow (for civil, agricultural, industrial uses, etc): the difference between inflow and outflow must guarantee, on each homogenous stretch, a flow which protects the typical biocoenosis of the water body considered.

Quality and quantity in the programme of measures

The WFD defines a programme of measures which includes "basic measures" (minimum requirements to be complied with) and "supplementary measures" (designed and implemented in addition to the basic measures).
For both, measures of quantitative protection of the water bodies are introduced. In article 11.3 (basic measures, table 16), controls are established over abstractions and impoundment, artificial recharge of water bodies and measures to ensure that the hydromorphological conditions of the water bodies are consistent with the achievement of the required ecological status.

The Directive defines a "non–exclusive list" of supplementary measures which aim to protect water quantity both on supply and demand side. Basic and supplementary measures must be selected with the aim to ensure a sustainable water balance and the minimum flow supporting the ecosystems.

Article 11.3
Basic measures are the minimum requirement to comply with and shall consist of : (…)
(e) control over the abstraction of fresh surface water and groundwater, and impoundment of fresh surface water, including a register or registers of water abstractions and a requirement of prior authorization for abstraction and impoundment. (…)
(f) controls, including a requirement for prior authorization of artificial recharge or augmentation of groundwater bodies. The water used may be derived from any surface water or groundwater, provided that the use of the source does not compromise the achievement of the environmental objectives established for the source or the recharged or augmented body of groundwater. (…)
(i) for any other significant adverse impacts on the status of water identified under article 5 and Annex II, in particular measures to ensure that the hydromorphological conditions of the bodies of water are consistent with the achievement of the required ecological status or good ecological potential for bodies of water designated as artificial or heavily modified. Controls for this purpose may take the form of a requirement for prior authorization or registration based on general binding rules (…)

LIST OF MEASURES TO BE INCLUDED WITHIN THE PROGRAMMES OF MEASURES: PART B
The following enumeration is a non-exclusive list of supplementary measures which member states within each river basin district may adopt as part of the programme of measures required under article 11(4): (…)
(viii) abstraction controls

(ix)	demand management measures, inter alia, promotion of adapted agricultural production such as low water requiring crops in areas affected by drought
(x)	efficiency and reuse measures, inter alia, promotion of water-efficient technologies in industry and water-saving irrigation techniques
(xi)	construction projects
(xii)	desalinization plants
(xiii)	rehabilitation projects
(xiv)	artificial recharge of aquifers (…)

Table 16 : measures of quantitative protection of the water bodies in article 11.3

Pricing policies and environmental objectives

Article 9 of the WFD indicates that 'the water pricing policies provide adequate incentives for users to use water resources efficiently, and thereby contribute to the environmental objectives of this directive'.
Therefore, water scarcity should be covered by incentive water pricing policies. The different water uses are concerned including at least industry, households and agriculture.
The directive specifies also that 'Member states may in so doing have regard to the social, environmental and economic effects of the recovery [of costs] as well as the geographic and climatic conditions of the regions affected'.

3.3.2. Social concerns

Socio-natural dynamics in the context of water scarcity

Under conditions of any type of resource scarcity, economically and politically disadvantaged social groups usually meet difficulties to sustain their livelihoods, their quality of life, and even their very existence. The objective of this section of the document is to explore the undesirable social impacts of water scarcity and the effect of its mitigation on our communities. By inference, this specification embraces the concept of livelihoods as well as lives and therefore includes threats to the economic viability of individuals and communities.

The number of citizens exposed to drought within the European Union is increasing. The same evaluation of people impacted by scarcity could be done for Mediterranean countries. Figure 24 shows the relevant data for 2002.

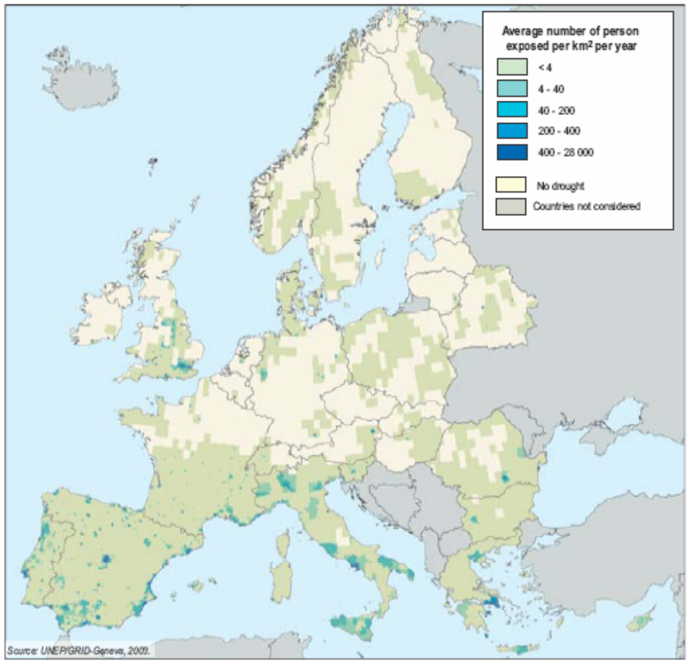


Figure 24: Average number of people per km exposed to drought (UNEP)

Scarcity of water resources can affect a wide range of social indicators, perhaps the most significant of which are:

- the affordability of water
- public health
- community cohesion

Recent and current EC funded research on the human and social dimensions to water stress and water management is represented by the projects (many of which are members of the Human Dimensions Cluster coordinated by the Harmoni-COP project) listed in the end of chapter III references.

Affordability of water

As resource managers seek to raise extra-capital for investment in new supply sources or improve the efficiency of current systems, the delivered price of water can dramatically rise. The issue of affordability, whilst of obvious concern to those working in developing nations, has latterly attracted increasing interest in Europe and the developed world (OECD, 2003). The literature on the affordability of water in the context of privatisation (Rodriguez, 2004) and willingness/ability to pay (Merrett, 2002) has been full of lively deliberations in recent years and has also prompted a wider debate on the human right to water (Bluemel, 2005).

Tariff structures in the developed world tend to reflect a desire that the basic human needs of water and sanitation should be accessible to all members of society regardless of financial circumstances. Where government has detached itself from influence over water pricing, or has set other performance criteria above this social imperative, affordability is under threat and needs to be regularly monitored although the phenomenon is not exclusively a problem for the water sector as it is also clearly related to low incomes. The social affordability, which is even a more sensitive topic in non EU Mediterranean could be investigated more in depth.

Public health

Where water scarcity is driven by climate change, there can be significant impacts on human health. Warmer, sunnier climates also encourage more recreational water use, leading to the increased exposure of leisure users to waterborne pathogens. The additional risks to human health from water stress mainly results from changes in the spread and activity patterns of pathogens and their intermediate hosts. For example, drought can induce malaria outbreaks following drought years (Chase et al., 2002) and recent research suggests that hemorrhagic fever may probably be associated to drought events (Acuña-Soto et al., 2005).

The Community cohesion

At higher scales of social organization, water stress can give rise to economic disruption and mass migration as agricultural systems fail. Loss of income (due either to the increased costs of securing access to water or of lower crop prices) and loss of land value (perhaps due to desertification) are obvious consequences of increasing water stress. However, this reduction in farming community wealth has consequences for other businesses which rely on the trade and patronage of farmers. The social, and often psychological, damage caused to farming families may well take several years to materialize as they struggle to adapt to changing climatic, environmental and production pressures. Working longer hours, delaying investment, selling stock, and taking on extra work off the farm (sometimes leading to the involuntary separation of families), are all well recognized adaptation mechanisms.

Scarcity conditions are also likely to raise new, or exacerbate existing, social tensions. Young people develop very negative impressions of farming as a livelihood. The strain placed on farming communities by water scarcity is often long-term and the end of a drought period rarely presages a sudden return to full production and the restoration of income levels.

Social impact of supply side responses

Supply side responses to water scarcity involve the increase of the volume of water available for use (though not necessarily potable use). The social impacts of supply side measures are unlikely to be as significant as those for demand side mechanisms, simply because consumers are largely unaware of any change in the supply regime. There are, however, three exceptions to this situation:

- Firstly, the beneficiaries of projects which augment provision to an existing supply network are those who already have access to the network. The social costs and benefits of such schemes can be poorly distributed amongst communities. For example, urban communities may benefit from a large inland desalinization scheme whilst rural communities are blighted by distillate treatment and disposal sites.
- Secondly, although there are excellent European examples of reuse projects for irrigation, industry and indirect potable uses through river and groundwater bodies, there is a wide variety of social (and institutional) issues surrounding the recovery, recycling and reuse of wastewaters. Whilst the technologies are well tested and economic conditions often favourable, societal concerns about the use of non-potable water can hamper attempts to implement reuse schemes. In summary, studies have identified that :
    - Communities across Europe are sensitive to water reuse issues unless they understand their urban water cycle and have confidence in quality control. This is more evident in the northern part of the continent than in the south even though many large cities in northern Europe depend on indirect reuse for their freshwater resource for potable treatment especially during dry weather flow.

  - Many corporate stakeholders are nervous about supporting reuse projects in the absence of clear and legally binding water quality guidelines.
  - Use of a water recycling system where the source and application are located within their own household is acceptable to the vast majority of the population as long as they trust the organization which sets standards for water reuse. Using recycled water from second party or public sources is less acceptable, although half the population shows no concern, irrespective of the water source. This situation is different for reuse in industry.
  - Water recycling is generally more acceptable in non-urban areas than in urban areas. This disparity is more pronounced for systems where source and use are not within the respondent's own residence.
  - Willingness to use recycled water, particularly from communal sources, is higher amongst metered households than non-metered ones, and higher amongst households which take water conservation measures than those that do not.
  - The use of recycled water for irrigation is widely accepted by farmers who believe them to be safer than river waters.
  - There are strong concerns about the sale of products which have been irrigated with recovered wastewater, especially vegetables. Farmers can overcome resistance through positive evidence from the consumers and the retailers that there will be a market for the products cultivated with the recovered water.
  - The establishment of standards for the reuse and management of monitoring programmes promotes confidence in reuse schemes.
- Thirdly, increasing water scarcity often leads to attempts to re-negotiate access or distribution rights to water resources. Stakeholder requirements and claims to legitimacy for those requirements will change as the resource becomes scarcer. Where existing rights are threatened, the very definition of an equitable distribution may be challenged and the spread of costs and benefits resulting from mitigation actions questioned. Existing management structures are not always capable of supporting such re-negotiation, particularly where there are competing uses.

Social impact of demand side responses

Encouraging water conservation is perhaps the most obvious policy instrument available to help professionals in their efforts to balance supply and demand. National and pan-national bodies tend to favour approaches or mixes of instruments they promote (often informed by local cultural and development considerations), although the overall effect of many strategies is that of a "carrot and stick" approach. Such demand side approaches rely on a range of instruments and techniques which can be divided into four broad categories:

- economic
- regulatory
- technological
- educational

A recent review of societal responses to these policy mechanisms can be found in Gearey and Jeffrey (2005).

Economic category

Design and implementation of economic policy instruments in the water sector requires awareness of the implications of such instruments and the impacts they may have on particular groups of users. The essential role of water in the lives of humans and its cultural status in many societies need to be respectively recognized and valued. Ability to pay for water, either as a commodity, a social good, or an environmental resource, varies across communities and through time. This fact, when combined to the nature of water as a primary good, raises issues of equity and fairness in water allocation (Herbert et al., 1995) ; particularly as the volumes consumed by some types of water use, such as drinking, are relatively inelastic to price. Availability of a reasonably priced supply of water has also been linked to regional and national economic growth, particularly in the agricultural and primary industrial sectors (Schama, 1995).

Evidence to support the view that economic instruments are effective in modifying water consumption behaviour is variable. Although the application of simple pricing instruments such as block rates has generated expected gross responses from domestic consumers, more detailed pictures of response envelopes have been difficult to construct. Different groups of water users clearly respond to economic instruments in different ways and at different times. Although many studies have demonstrated a link between water price and consumption, results from a study carried out in the Netherlands reported by Achttienribbe (1998) recently raised serious doubts about the price elasticity of water consumption in different sectors. The motivation to save money (a financial incentive) rather than to save water (an environmental incentive) has been demonstrated to be the dominant driver for reactions to many conservation initiatives.

Regulatory category

Regulatory based demand side measures can include mandatory and enabling legislation, regulations, policies, standards and guidelines. They can be used to reduce institutional, legal or economic barriers for a more efficient water use or to create barriers against unnecessary or wasteful water consumption. Whilst the use of regulatory measures can generate a more predictable and immediate effect on consumption patterns, there are a number of considerations to be taken into account :

- Firstly, the perceived legitimacy of a regulatory measure can significantly influence its impact. Communities will ask questions about whether the regulation is based on a sound and broadly accepted understanding of the problem, and the credibility/ competence of the regulating body in setting the measure. They will also be concerned about the fact that any price increase is not being used to take advantage of the situation to increase profits.
- Secondly, many regulatory measures rely on effective monitoring and enforcement, activities which in themselves are resource consuming.
- Finally, and as it is the case for any regulatory measure, evasion, deception, and abuse will adversely impact the effectiveness of the instrument and challenge its credibility as an effective policy instrument.

Technological category

Technological instruments include structural or physical improvements to water supply and use systems and installation of water efficient devices or processes (such as low flush toilets or low flow showers, etc). Difficulties associated to technology based policy instruments typically concern the availability of complimentary knowledge and skills required for effective deployment. In addition, new technologies cannot simply be located in our houses, streets and utility infrastructures without some understanding of how they impact existing system performance. Public responses to retrofit programmes (eg. supply and fitting of low volume cisterns) has been shown to be positive if the equipment is offered for free and if the programme is high-profile and aggressively managed (Sarac et al., 2002). However, initiatives may be rejected on aesthetic and practical reasons, particularly if bathrooms or kitchens have recently been refurbished.

Educational category

The education of water users through different contact routes and media is largely utilized to modify water use behaviour and encourage voluntary water conservation actions. Often seen as the core instrument for use in long-term conservation strategies (Grisham et al., 1989), educational programmes make use of printed, video, and audio media as well as face-to-face methods. Developments in the fields of participative planning and social learning have influenced the design and execution of this type of water policy instrument as more consensual and community informed approaches to water management have been developed. Indeed, although the term “education” has traditionally been used to characterize this form of water policy instrument, there is increasing impetus to use a term which better reflects the collaborative nature of the process (e.g. “communication”, or “dialogue”; the latter of which being the preferred term here).

Dialogue, as noted above, is an instrument which encourages behavioural change. Consequently its effectiveness is posited on the assumption that beliefs determine values, values determine attitudes, and attitudes determine behaviour. However, the ability of attitudes to predict behavioural intentions and overt behaviour continues to be a major focus of theory and research in psychology and it is now generally recognized that although attitudes are relevant for understanding and predicting social behaviour, many important questions remain unanswered. Indeed, many studies, such as that conducted with specific reference to the water sector by De Oliver (1999) tell us that none of these links can be taken for granted, and that measuring the causal process is itself a non-trivial activity. These limitations to managing water use behaviour through dialogue have led to calls for more targeted campaigns, greater public participation during the early stages of programme design, best practice exemplarity to demonstrate the benefits of conservation and programmes which generate a commitment to act.

Social vulnerability and adaptation

Social vulnerability to natural hazards such as drought and water stress is a function of the ability to predict the occurrence of the hazard, the resources available to cope with the hazard, the particular features of the existing economic system, and the ability to adjust and adapt to changing conditions. Whilst the resilience of social networks is often challenged by conditions of water stress, social resilience can work to prevent degradation resulting from overexploitation of land in response to drought. Recent advances in the theory of social adaptation has emphasized the ability (or inability) of a social entity to cope with the increasing demands caused by water scarcity, describing a second-order scarcity (Turton et al., 1999) of social resources which acts as a barrier to adaptive change.

Before a solution can be offered to the problems of increasing water stress, we need to begin to define what is individually and communally acceptable as response options and what the barriers are to adaptation. One barrier may be convenience. Given that water supply in the many parts of the world is universal and that there are few barriers to delivery, access couldn’t be easier. Low levels of water metering and relatively low pricing, signal to the market that the product is cheap and abundant. Asking people to change their consumption patterns needs to be correlated with an explanation about why a change is needed. Another barrier to adaptation may be awareness : although people are aware of global warming, the uncertainty of predictions means that a guaranteed prognosis cannot be delivered. A third problem might be the cultural significance of water ; hygiene, health and prosperity are all linked to access to water – for some it represents modernity at its highest apex. The goal is to identify what triggers need to be put in place before individuals and communities accept their responsibility in cutting water demand. Without this shift in attitude, policy targeted on individual and community consumption will face legitimacy problems. The key to tackling individual and community consumption will be to recognize that consumers are not homogenous groups : in the same way that market consumption is heterogeneous, so is water use.

Indeed, the extent to which communities are able to adapt to increasing water scarcity has been represented in a Social Water Stress Index (Ohlsson, 1999). This SWSI represents a society's social adaptive capacity in facing the challenges of physical water scarcity. It is calculated as the ratio of :

- A standard measure of water stress/scarcity, arrived at by dividing the amount of annually available renewable water by population size, to
- the Human Development Index for each country. A higher value indicates a greater degree of water stress.

The cultural significance of water

Any discourse on water consumption is predicated on cultural understandings of water and its institutional framework. In many countries the institutional framework is based on private property rights – access to water "belongs" to a person or institution, whether private or public. There is no universal access to water and the rights to water are not based on the needs but on legal entitlement. This is not the place to review water rights but this brief outline helps to select the type of literature that could inform further research. The work conducted by Aguilera-Klink et al. (2000) is exemplary in this area : deconstructing concepts of water scarcity, the authors are able to build a strong argument about what explains the development of a society's water structure, what shapes attitudes towards water and examine how consumption patterns become engrained within an institutional framework. It does not only cover the way water is accessed and priced but also highlights that perceptions of scarcity can create "panic consumption" leading to more acute conditions of scarcity. By linking progress with water, consumption creates its own dynamism cemented within power structures in society. This paper is one of the few to emphasize how power relations and water have a direct effect on consumption levels. What is also made clear is how those with a direct dependency on access to water have specific local knowledges (seasonal water flow, depth of aquifer) but limited understanding of the holistic hydraulic process.

Water use, perceptions and attitudes to water and water governance adaptivity must include a perspective on how water acts as a conductor of power and gender relations, how it becomes representative of forms of knowledge and means of operating power/knowledge discourses. We cannot talk about human behaviour without recognizing that we also need to talk about power. Behaviour is learnt and is socio-cultural, we learn to adapt to our environment. Part of that process is gaining knowledge and as a consequence, our actions help us move through the various networks of power that exist in our society. Using power as a theoretical underpinning enables us to analyze water as a vehicle of control rather than just as a social or economic good.

Concluding comments

Although research into the social dimensions of water scarcity has increased (and its quality improved) over recent years, effective knowledge exploitation is beset by two problems :

- Firstly, the knowledge base itself is dispersed and typically located within the confines of a disciplinary community such as sociology or anthropology rather than with water management per se. It is thus difficult for water sector professionals to locate relevant knowledge (in both terms of research findings and knowledgeable individuals). Possible responses to this issue are difficult to envisage although dedicated publications or events which provide an opportunity for commercial concerns to access contributions on the human dimensions of water management would be of benefit.
- A second problem is that many organizations in the water sector are poorly equiped to recognize and exploit the potential contributions of the "softer" sciences. Decades of emphasis on engineering, technology and infrastructures

> has left its imprint on water supply and management institutions to the extent that the only incentives to understanding any human association with water is in terms of marketing (selling people the products of engineering) and public relations (convincing people of the benefits of engineering). However, the issues here go deeper than the educational background of individuals. Studies of human behaviour or attitudes typically produce results of low predictive power. However, this does not mean that they are of no value. Research contractors need to identify the contribution of such studies before they are executed and accept that they are more likely to 'inform' than 'resolve' a particular problem.

The role the Water Framework Directive (WFD) could play in facilitating socially just and equitable responses to water scarcity is worth noting. The simple fact that River Basin Management Plans are to be prepared through a transparent and consultative process is important in this context. Such forms of planning provide opportunities to anticipate scarcity conditions, scope possible responses, rehearse arguments to support specific options and learn about other stakeholders perspectives, concerns, constraints and policy preferences. Consequently, some of the tensions discussed in earlier parts of this chapter will not happen.

The WFD, whilst inviting member states to "take into account the principle of recovery of the water services costs", avoids imposing full cost recovery as an economic principal for water services provision. This will empower governance bodies by enabling them to support vulnerable groups without compromising their commitment to the WFD ; a potential social safety net which could be very useful under conditions of water scarcity – as discussed above.

Finally, article 14 of the WFD provides a mechanism for addressing social learning, participative planning and gender issues. By extending the consultation franchise to previously unengaged groups, article 14 facilitates inclusion and will give a voice to social concerns. The extent to which such concerns will be acted on remains an open question. However, there is little excuse for social concerns not to be registered and brought to the attention of decision takers.

The economic, environmental and social development of our communities co-evolves with the availability and quality of water, and we need to enrich and deepen our understanding of these relationships. Sustainable development is fundamentally about the adaptive capacity of the human race. In relation to water, the broad objective should be to enhance adaptive potential in the context of safeguarding water supplies, not only for human consumption but also in support of viable ecosystems. People adapt and change at a faster rate than policies, technologies and infrastructures. The challenge is to understand this potential as it impacts on water supply, and exploit it as a beneficial tool for adaptive response.

3.3.3. Economic profitability

With growing water scarcity and increasing competition between water-using sectors, the need for water savings and more efficient water use has raised in importance in water resources management. Improvement in the physical efficiency of water use is related to water conservation through increasing the fraction of water beneficially used over water applied, while enhancing economic efficiency is a broader concept seeking the highest economic value of water use through both physical and managerial measures.

Economic efficiency of irrigation water use refers to the economic benefits and costs of water use in agricultural production. As such, it includes the cost of water delivery, the opportunity cost of irrigation and drainage activities, and potential third-party effects or negative (and positive) externalities (Dinar, 1993). Economic efficiency can be expressed in various forms, for example, as total net benefit, as net benefit per unit of water, or per unit of crop area and its broader approach compared to physical efficiency allows an analysis of private and social costs and benefits.

Economic efficiency at the basin scale seeks to maximize the net benefits of water uses in the whole basin. The concept can take positive and negative externalities in water use, for example, among upstream and downstream demand sites (irrigation systems), water productivity (output per unit of water consumption), as well as physical efficiencies at the system level into account. In addition, the concept can relate water uses across water-using sectors. However, this issue is not addressed here[29].

Several writers (Kolderie, 1989 ; Wunsch, 1991 ; Ostrom et al., 1993) distinguish between the responsability for "provision", which might be government's concern, and "production", which might be done by private or community actors. A clearer distinction is made between (a) "direct provision", which is the act of physical producing (constructing, creating, maintaining) and delivering a service, and (b) "indirect provision", ensuring that a service is available by setting policy and service standards, coordinating, financing, enabling and regulating producers. As water is a basic need for life, direct and indirect provision have to be realized with efficiency and equity for a good allocation and management of water. Then the question of which type of service, public or private, is the most adapted is very important. There is no universal answer to this question. Every water system that proposes an efficient and equitable service can be performant. The choice between a public and a private service has to be done by taking into account the advantages and disadvantages of the service in accordance with the local context. However, co-management between public and private sectors can be a good solution for "direct" and "indirect" provision. Table 17 sums up the advantages and disadvantages of different water allocation mechanisms.

Allocation mechanism	Definition	Advantages	Disadvantages	Example
Marginal cost pricing	Targets a water price equal to the marginal cost of supplying the last unit of that water. Water supply charges typically include • collection • transport to treatment plant • water treatment to meet quality standards • distribution to customers • monitoring and enforcement. Water charges may also include any social costs (or benefits), although they may be more difficult to calculate.	• Avoids the tendency to underprice water • Could avert overuse because prices would rise to reflect the relative scarcity of water supplied • Can also be combined with pollution charges or taxes	• Difficulties in defining marginal cost itself as a result of problems in collecting sufficient information to estimate benefits and costs • Tends to neglect equity issues • Requires volumetric monitoring which is not always in place	Irrigation in France Water is sold on the 'binomial tariff' basis. The Société du Canal de Provence designs tariffs with the objective that they reflect long-run marginal capital costs in the peak period, operating costs only in the off-peak period, and possible discharge reduction in the form of pollution fees. Thus the State subsidies 50 % of all elements of the tariff.
Public/administrative allocation	The government decides which water resources can be used by the system as a whole, and allocates and distributes water within different parts of that system. The State's role is particularly strong in intersectoral allocation, as it is often the only institution that includes all users of water resources, and has jurisdiction over all sectors of water use.	• Tends to promote equity objectives, ensuring water supply to areas of insufficient quantity; the physical allocation of water among the users is independent of the charge	• Prices do not represent either the cost of water supply or its value to the user • Often leads to waste and misallocation of water • Often does not support user participation. • The dominant incentive to comply is enforcement by law. • The structures or fees for water often do not create incentives for users to save	

[29] See website: http://www.ifpri.org/divs/eptd/dp/papers/eptdp72.pdf

			and use it more efficiently.	
Water markets	The allocation of water is referred to as an exchange of water use rights, compared to a temporary exchange of a given quantity of water between neighbouring users. Sometimes it requires the intervention of government to create the conditions necessary for markets to operate (defining water rights, creating the institutional and legal framework, investing in infrastructure to allow water transfers)	• The seller has the opportunity to increase profitability • The buyer benefits because water market encourages increasing water availability • Empowerment of water users by requiring their consent to any reallocation of water and compensation for any water transferred • Provision of water rights tenure to the water users • Induces a shift towards improved water management and efficiency in agriculture	• Difficulties for establishing the market: measuring water, defining water rights when flows are variable, enforcing withdrawal rules, investing in conveyance systems, environmental degradation • Third-party effects have to be identified and quantified to take into account the associated costs in the exchange process (pollution, overdraft of water tables, etc.)	
User-based allocation	Irrigation: farmer-managed irrigation (by time rotation, depth of water, area of land, shares of the flow). Domestic-water supply: community wells and hand-pump systems. User-based allocation requires collective action institutions with authority to make decisions on water rights. The effect of user-based allocation depends on the content of local norms and the strength of local institutions.	• Potential flexibility to adapt water delivery patterns to meet local needs • Administrative feasibility, sustainability and political acceptability	• Requires a very transparent institutional structure • Local user-based institutions can be limited in their effectiveness for intersectoral allocation of water because they do not include all sectors of users	Communal irrigation system In Portugal (Vila Cova village), issues such as beginning and ending of the irrigation period, losses in canals, travel time of water, user sequence, and night turns are addressed via various arrangements that involve different community institutions.

Table 17 : Water allocation mechanisms (Lallana et al., 2001)

CONCLUSIONS - RECOMMENDATIONS

Water scarcity and drought management are huge challenges in the Mediterranean. Scarce water resources, intensive water competition between users - in particular agriculture and tourism-, frequent drought episodes are common challenges in the Mediterranean.
The Middle East and North Africa (MENA) region basically 'ran out of water in the 70s' (Allan, 2002) and today depends as much on water from outside the region – in the from of its food import, for example- as on its own renewable resources ((Tropp, 2006). However, European countries are also impacted by low levels of water availability and share the same concerns regarding water resources management.
In addition, in the light of climate change, intensity and frequency of droughts are estimated to increase.
Unsustainable water management including water over-consumption and water pollution as well as possible climate change effects in a water scarcity situation could result in severe impacts on nature and society.

Prevention and mitigation of water scarcity situations and drought episodes are becoming essential components of water policies in the region.

1) Water scarcity and drought and the Water Framework Directive in the Mediterranean

The European WFD provides a basis for integrated water resources management. Although the WFD is not directly designed to tackle quantitative issues, it allows enough flexibility to take into consideration water scarcity and drought. Indeed:
- The directive is a “framework for the protection of waters which prevents further deterioration” (articles 1.a and 4)
- The directive contributes to mitigate the effects of droughts (article 1.e).
- Water quantity can have a strong impact on water quality and therefore on the achievement of good ecological status.
- “Good quantitative status” is required for groundwater ; a balance between abstraction and recharge must be ensured. Furthermore, groundwater levels should not be subject to anthropogenic alterations that might have impacts on surface waters.
- The directive requires water pricing policies to use water resources efficiently.

For these reasons:

- When developing the WFD Programmes of Measures (POM) and associated River Basin Management Plans (RBMP) (articles 11 and 13), quantitative and qualitative aspects should be jointly considered for the plans and programmes to be coherent and to create synergies where possible. Quantitative issues should, in particular, be taken into account when setting the objective of “no further deterioration” of current status (articles 4.1, 4.5, 4.6 and 4.7).
- Actions to manage water quantity (e.g. water scarcity) should be considered as “measures” (basic/supplementary) when developing the WFD POM and associated RBMP (articles 11 and 13).
- When and where needed, a specific “drought management (sub)plan” should be included in the WFD RBMP (article 13.5).
- Public participation (article 14) should also be organized around water scarcity management issues, as required by the WFD.

Regarding derogations, “prolonged droughts” are introduced in the directive as force majeure events. Therefore, clear definitions of what is understood by “prolonged droughts” will have to be established.
Specific aspects of the implementation of the WFD linked to water scarcity and drought are being further analysed by a group of EU experts[30]. This concerns in particular Agriculture measures, exemptions (concept of 'prolonged drought'), groundwater aspects and links with climate change.

With regards to Mediterranean non-EU countries, and apart from the timeframes of the Directive, which are not relevant for non accession countries, specific attention is required on the way to adjust water management practices towards the WFD approach in the Mediterranean context.

In this respect, the following issues have been identified (MED-EUWI GWWG, 2007):

- The concept of 'river basin district' can not be applied where aquifers are not directly linked with surface water and therefore the concept of *river* basin is not relevant. This is the case for the Nubian Sandstone aquifer. There, a management structure should be set up at the level of the aquifer itself.
- Most major groundwater aquifers in North Africa including the Nubian Sandstone aquifer and the North Sahara Aquifer are fossil non-renewable groundwater aquifers with very limited recharge potential. In these cases, a balance between abstraction and recharge is impossible to accomplish.
- The use of economic instruments, such as water pricing, can be difficult in some countries where people believe that water is a priceless (i.e. precious) public resource that should not be value-priced, but rather charged on operation and maintenance cost recovery.
- Regarding the cost-recovery principle, the flexibility offered in the directive which states that 'Member States may in so doing have regard to the social, environmental and economic effect of the recovery as well as the geographic and climatic conditions of the region affected' (Art. 9.1) has to be considered with attention by neighbour countries where the social and economic level is lower than in the EU.

Only detailed analysis would allow identifying in detail the feasibility of implementing the WFD requirements in neighbouring countries.

2) *Water scarcity & drought and Risk management in the Mediterranean*

Climate change, drought, and permanent water scarcity are interrelated, but these processes should not be confused, or interchangeably referred to, if the complex issues of drought and water management are to be addressed on a sound scientific basis.

Permanent water scarcity or permanent deficiencies are related to natural aridity, permanent over-exploitation of available resources and hence unsustainable water management, or desertification if aggravated by human footprint, while temporary water imbalances deal with the natural hazard event of drought, often in combination with human activities with increased water demand.

The traditional mindset has been to react to drought with a crisis management approach, through the provision of emergency assistance to the affected areas or sectors. By following

[30] Water Scarcity and drought Expert Network of the Common Implementation Strategy of the Water Framework Directive, 2007-2009 http://ec.europa.eu/environment/water/water-framework/implementation.html

this approach, drought only receives the attention of decision makers when it is at peak levels of intensity and spatial extent and when water management options are quite limited. This approach is sometimes referred to as the "hydro-illogical cycle" where concern and panic lead to a reactive response to associated economic, social and environmental impacts, followed by apathy when precipitation restarts and water resources return to normal. This approach has been characterized as ineffective, poorly coordinated and untimely.

Drought planning tendencies nowadays develop towards moving from crisis to risk management. Developing comprehensive, long-term drought preparedness policies and action plans may significantly reduce the risks and vulnerabilities associated to extreme weather events.

Institutions, governments and stakeholders should play a leading role in the implementation of a new vision for the water resources management. This vision could be summarized as considering that fresh water is a scarce and valuable resource that should be carefully managed in the long-term perspective by respecting the following conditions. In more details, this implies:

- For functioning freshwater ecosystems to fulfil basic socio-economic and environmental needs. Indeed, prioritizing the uses, including the environmental "use", is a necessity in order to achieve sustainable water management on a multi-criteria basis (usefulness, quantities consumed, season, etc). The important point is to affirm the principle that drinking water supply is the priority usage.
- Promotion of participation, partnership and active cooperation for sustainable water management at local, national, and international scale :

  - Water management should be defined at a local scale in order to be adapted to local environmental, social and economic context. This local scale is proposed to be the river basin scale of the WFD.

  - Involvement of the concerned local actors in water management projects should be considered as a key issue for the sustainability of the projects.
- Knowledge is a key aspect for a sustainable management of water resources within River Basin Management Plans. Sound knowledge about water availability and quality as well as its real use by different users is required. Water management must be realistic and produce sound estimates of water needs by aquatic ecosystems and human activities that depend on water.
- Where necessary (in case of resources overexploitation), authorities should implement a combination of measures for both demand and supply sides for all users in a coherent river basin programme to restore the equilibrium. The role of administrative institutions should be stressed to improve the equilibrium between supply and demand management. Thus institutions should deal with the human and economic resources to effectively cope with this challenge.

In the core of possible measures to be set up, some are emerging due to their important impact on the biggest water consumers and to their short-term effects:

- For demand-side measures :

  -Changes in water consumption promoting subsidies, especially of the CAP in the European Union.

  -Reduction of leakages in the distribution networks.

  -Improvement of irrigation technologies by improving agricultural management, optimizing soil water utilisation and irrigation, and setting up new programmes of practical research in order to reduce water consumption (e.g. crop rotation, genetic variety).

-Identification and implementation of potable substitution opportunities where appropriate quality of reclaimed water can be used for non drinkable applications to increase drinkable water availability.

-Evaluation of the advantage of setting up water banks and quota systems.

-Setting up an adapted tax and price policy system to encourage investments or demand approach management development, and to develop financial mechanisms to internalize external costs and anticipate profits on water savings.

-Development of education and awareness campaigns

- For supply-side measures :

  -Preservation of the functioning of natural catchments and restoration.

  -Improvement of an efficient use of existing water infrastructures such as dams or inter-basin water transfers.

  -Setting up an obligation for using a costs / needs / advantages / alternative solutions analysis for every project of new water resource creation.

- Evaluation of effectiveness and efficiency of the proposed measures.

Cost-effectiveness analysis has a role in the prioritization of the measures addressing water scarcity and drought. Demand-side measures have to be prioritized except if the cost-analysis indicates the contrary.

There is a need for a deeper analysis of some measures mentioned above to be implemented in the River Basin Management Plan / Drought Management Plan.

Finally, the guidelines established through the MEDROPLAN project should be used to guide Drought management plans development in the Mediterranean.

3) Water scarcity and drought and the need for further research in the Mediterranean

Future research and action priorities for supporting water scarcity mitigation in Mediterranean basins:

Water scarcity and data scarcity on water related issues are strongly correlated and limit the sustainable management of water resources in semi-arid areas. While there is substantial work on specific hydrological issues on the process level, and also extended knowledge on irrigation techniques, aspects of IWRM or basin management in general are suffering from a missing deeper understanding of how water resources are deteriorated over time and space, and therefore how future changes may even worsen the situation.

In particular, this is related to a limited understanding of how pollution and water quality aspects are affecting the availability of safe water resources, and where the deterioration of water quality requires a wider consideration within basin management plans and the implementation of the EU Water Framework Directive.

Missing information about the critical role of water quality is superposed by a strong competition on limited water resources, resulting in a strong role of stakeholders with particular interests. The more the water resources are already limited, the more the regional population is felt directly depending on water as a rare good, often resulting in many objections which limit the flexibility to explore alternative approaches.

So, in short, there are two main domains affecting sustainable planning a) the knowledge on water resources and b) the social economic component. While this appears trivial and well known, it is often ignored in the public discussion that both aspects are interconnected, and limited knowledge may also prohibit any rational sustainable planning or public participation. Even worse, there is still a lack of methodology to be used for an integrated risk assessment and the organisation of adaptive risk management strategies.

In this context risk management in dry land basins has to address both

a) the temporary and/or recurring onset of droughts due to a limited water availability, and
b) the water stress by periodical or unforeseen overexploitation or pollution hazards.

The risk management needs to address both the set up of strategic frameworks as well as the implementation of concrete technical and non-technical options.

Consequently, for dry land basins the implementation of integrated basin management plans, including drought management issues, appears much more difficult than in basins of the northern hemisphere.

One of the specificities of water in the Mediterranean countries (apart from the problem of water scarcity) is the fact that coastal zones show high densities of population and concentrate nearly all of the domestic, agricultural and industrial activities. A significant proportion of the wastewater production is concentrated along the coast and has a significant impact on the water quality of the Mediterranean Sea. Being of major importance for the local economy, including aquacultures and tourism, a good ecological status has to be maintained also during droughts and increasing water scarcity.

In the MENA region, as well as in water scarce regions of Africa and Asia, sufficient water availability to meet the growing need of the increasing population is going to be a major challenge. This includes all water related sectors, as needs for humans, agriculture to produce more food, concentrated animal industry for meat proteins, and other industrial and recreation uses.

The following paragraph will introduce a number of themes, which are considered as critical key issues to improve the integrated water resources management and water stress mitigation in dry lands. Water scarcity is perhaps the over-arching issue, and most of the other issues arise from it.

Hydrological inventory/monitoring

The inventory of catchment areas, and (seasonal) outflows from Mediterranean catchments needs to be extended. At present, dryland catchments and smaller catchments, though representing a significant contribution to the total area, are not well represented within published literature or the WFD.

Independently of any research or planning of management options, the database has to be improved by the set up of monitoring stations and adapted sampling campaigns. It is of specific need to gather detailed water quality information during the initial part of floods.

Pollution dynamics

The fate of chemicals (all forms of nitrogen, phosphorus, etc), point and non-point sources in dependence on soil moisture or duration of the dry period need to be better understood. This should include:

- Investigation of pollutant accumulation on agricultural lands (fertilizers, agrochemicals, adsorbed metals) during the dry period and its impact on remobilisation.
- Toxic pollutants such as pesticides and heavy metals.
- Impacts of storms and floods on pollutant remobilization from agricultural lands and municipalities.
- Securing water supply by mitigating toxic algae blooms in reservoirs.

Desertification and land transformation

Dryland priorities interlock with issues of desertification, fire management, and the conservation of both wetland and dryland areas of scientific (geological and ecological) interest.

Interactions between desertification mechanisms and water security still need further attention. This is especially the case for the ongoing soil salinization and ineffective irrigation schemes.
Here, a vast gradient of knowledge and practice within MENA countries and the European Mediterranean countries exists, and information/experience exchange still needs the highest attention.
The applicability of biodrainage and low cost remediation practices are of particular interest.

Treatment options

In many cases, countries and communities lack financial means for treating wastewater as required. At times, raw sewage and direct effluents from industry and animal production systems are directly discharged to water bodies.
To reduce water quality deterioration, there is a need to extend the use of adapted wastewater treatment for manufactures and small industries, in particular in the MENA region. Focus must be on simple, safe, and cheap technologies for wastewater treatment and reclamation.

Risk/Vulnerability assessment

Risk Assessment as issued by the WHO needs to be extensively implemented in practice, especially for tap and reclaimed water to extend the currently limited experience and lack of practical data (i.e. analytical data).
Increased effort on the vulnerability assessment will support a justifiable selection of urgent action areas as well as the identification of non-monetary benefits related to the implementation of mitigation options.
Risk and vulnerability are not only related to the sensitivity of the water resources under use, but also to climate conditions and human behaviour determining consumption. This is related both to unpredicted short-term events, as well as to long-term predictions of climate change effects.
It is important to refine our prediction methods to be able to understand how people behave when faced with risk and uncertainty. Methods are required that enable the characterisation of people's risk preferences and to integrate these risk preferences in policy making. Without such integration, any policy that aims to improve dryland water management will fail, as it will not be compatible with human behaviour.
Results of the vulnerability and risk assessment have to be used in the determination of Water Safety Plans / Drought Management plans.
Methods should be provided to overcome restrictions of existing simulation models and to enable a more comprehensive assessment of the predicted effect of management options.

Risk management - Strategic frameworks

Dryland areas lack an overall plan for sustainable future planning, at regional, national, and international scales. This includes strong interactions between the domestic water consumption imposed by growing urban areas along the coasts, waste disposal loads and agricultural water needs.
There is a need to envisage an efficient development of sustained Droughts Early Warning Systems, which include also the enhanced accompaniment of drought effects over the existent water uses, and the prediction of overexploitation.
The coordinated drought management needs to be adapted in particular for transboundary river basins, with the countries involved contributing with compatible information, in order to set up the necessary drought management instruments (like drought plans) at river basin scale.

Apart from it, the use of non-conventional resources (reclaimed water, stormwater...) is not really being applied, up to now. Here, a commonly agreed rule/regulation on reclaimed water quality must appear in the Mediterranean (the same water quality for the north and the south of the Mediterranean), because of the crop products movement from south to north. Enhanced operation of water infrastructure and dams Even if dams and canals are classical approaches to redistribute the hydrological availability of water in dry lands, their optimised use has, in most cases, not been fully exploited.
This may be related to adapted strategic reserves (also for addressing climate and global changes), as well as to a combined consideration of water quality and quantity.
Therefore, future activities could focus on developing adapted dam operation strategies for mitigating droughts (also taking into consideration the potential changes from hydropower use or irrigation towards drinking water supply).
Additionally, there is a need to adapt the technical design of dams, spillways, and operation to enlarge storage capacities for drought mitigation.

Economic instruments

There is an ongoing need to adapt economic instruments taking into account of

- water efficiency and investment in water saving technologies
- water pricing, incentives and equity in irrigation schemes
- virtual water trading and its implication for river basis management.

Additional work is needed to quantify the impact of low quality irrigation water on crop productivity, nutrition, as well as on public health in economic terms.

Adapted irrigation strategies

There is still a need to increase knowledge in the field of plant physiology (under field conditions), as well on technical designs to improve the drainage water reuse or the agricultural practices for an increased use of saline water.
However, to support an effective drought or water stress mitigation, work should be concentrated on a more comprehensive assessment of food security, economic growth (especially in developing countries), soil degradation and desertification, and the impact on water quality in ground and surface water resources.

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ANNEX 1

Country		Renewable natural water resources (internal and external) average per capita in m3 year		Exploitation Index (%)	
		2000 a	2025 b	2000 d	in 2025 following trend projection d
Spain		2738	2520	31,6	34
France		3197	2989	17	15,4
Italy		3315	3397	22	19
Malta		128	116	50	30
Slovenia		16 202	16 925	4	4,4
Croatia		15 849	16 717	1,1	1,7
Bosnia & Herzegovina		9748	10024	~2,7	3
Serbia & Montenegro		19 772	20 373 c	~6,2	5,7
Macedonia FYR		3184	3125	29	30,5
Albania		13 619	11 969	3,4	7,2
Greece		6765	6645	11,7	11,2
Cyprus		992	769	37,8	33
Turkey		3396	2558	15,3	24
Syria		1562	935	54,5 e	65 e
Lebanon		1413	1117	26,9	36
Israel		274 c	191 c	107	111
Palestinian Territories	West Bank	~ 375	~ 206	22,7	73
	Gaza	~ 49	~ 20	232	357
Egypt		866 e	576 e	83 e	94 e
Libya		155	103	200	75
Tunisia		478	380	51,4	56
Algeria		470	334	21,8	30
Morocco		992	720	39,4	54

Table 18 – Two indicators to evaluate the situations of water shortage present and future in Mediterranean area

a- According to demographic statistics UN 2003
b- According to population projection UN 2003, « variable medium »
c- Of which Montenegro alone: ~ 25 000
d- Source : Plan Bleu 2004
e- Reported to the actual resources

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