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European Topic Centre
Inland, coastal, marine waters

Vulnerability to Water Scarcity and Drought in Europe

Thematic assessment for EEA Water 2012 Report

ETC/ICM Technical Report 3/2012

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Abbreviations

EEA – European Environmental Agency
ETC/ICM – European Topic Centre on Inland Coastal and Marine Waters
EC – European Commission
EU – European Union
MS – Member States
WFD – Water Framework Directive
WFD-CIS – Water Framework Directives Common Implementation Strategy
RBD - River Basin District
RBMP - River Basin Management Plan
WSD, WS&D – Water Scarcity and Drought
DMP - Drought Management Plan
WSDMPs - Water Scarcity and Drought Management Plan

EG – Expert Group
EG WSD - Expert Group on Water Scarcity and Drought
WEI – Water Exploitation Index
WEI+ - Water Exploitation Index +
WISE-SoE – Water Information System for Europe – State of Environment
EDO – European Grought Observatory
DPSIR – Drivers, Pressure, State, Impact, Response
GWBs - Groundwater Bodies
LTAA – Long-term Annual Average

Executive Summary

The current report aims to provide in-depth information about the problem of Water Scarcity and Drought (WS&D) in Europe. It targets the identification of the drivers, pressures and impacts and the possible quantification of the problem, while it explicitly addresses issues of vulnerability. A wide selection of case studies is provided in order to capture different angles of the vulnerability to WS&D, touching on the industrial and agricultural sectors, the energy sector, the protected areas and ecosystems, the small water bodies and isolated islands etc. Climate change scenarios and future projections of the evolution of both drought and water scarcity phenomena are discussed, while current adaptation measures, focused both on demand and supply management, along with the progress of their implementation and future needs are highlighted. The report has been based on a vast collection of data and information from various sources and has furthermore been commented on by Eionet in a country review. It is provided as a background thematic assessment to the EEA Report "Water resources in Europe in the context of vulnerability" (EEA, 2012b).

Water scarcity occurs where there are insufficient water resources to satisfy long-term average requirements. It refers to long-term water imbalances, combining low water availability with a level of water demand exceeding the supply capacity of the natural system. Although water scarcity often happens in areas with low rainfall, human activities exacerbate the problem, in particular in areas with high population density, tourist inflow, intensive agriculture and water demanding industries. In the near future, it is likely that predicted climate change will aggravate this situation in the most water scarce parts of southern Europe, but could also affect areas which do not currently face such problems. In view of the problem, the European Commissions issued in 2007 a Communication on Water Scarcity and Droughts, setting seven specific pillars, such as putting the right price tag on water, fostering water efficient technologies and practices, improving drought risk management, enhancing a water-saving culture, improving knowledge and data collection, etc., and proposing a way forward. Follow-up reports of this Communication, assessing the advancement of the individual Member States and of the EU as a whole, have been issued annually (EC, 2012a), while a fitness check of the action and new policy recommendations have been launched in the 2012 EU Communication "A Blueprint to Safeguard Europe's Water Resources (EC, 2012b).

Traditionally, most attempts to manage drought and water scarcity and their related impacts focused on a rather reactive crisis management approach resulting thus in being ineffective, untimely and unsustainable in the long term. Currently there is a tendency to move forward in a proactive risk management approach in order to increase the resilience and sustainability of the affected regions. This transition from crisis to risk management is challenging since governments and individuals are accustomed to a reactive approach and little institutional capacity exists in many European countries for altering this behavior. The current report attempts to improve our current knowledge on water scarcity and drought in Europe, by quantifying water scarcity and drought phenomena across Europe, presenting the main drivers and pressures, illustrating the various impacts experienced by the Member States, addressing key issues of vulnerability, while presenting selected adaptation policies and measures and various scenarios.

Chapter 1 provides an introduction, stating the problem of water scarcity and drought, presenting the current EU policy setting and discussing the use of the Drivers-Pressures-State-Impact-Response as a basis for the assessment of water scarcity conditions.

Chapter 2 addresses issues regarding the quantification of water stress across Europe. It presents information on the occurrence of drought and water scarcity (current and past conditions), based on a vast collection of available data and information, including indicators.

Mapping of drought episodes suggests that we can observe an increase in the number of countries affected by drought per decade from 1971-2011, while drought occurrence has significantly increased in the period 2001-11, not only in the South and Central EU, but also reaching now the North and Eastern parts of the EU. Information from the WFD RBMPs also indicates that droughts are not only characteristic for river basin districts in Southern Europe, and occur in many other regions across the EU. While quantifying drought (meteorological, agricultural, and hydrological) is feasible, the quantification of water scarcity is more challenging as it is at the crossroads between environmental and social phenomena. Yet, at least 11% of the European population and 17% of its territory have been affected by water scarcity to date (EC, 2007a). Adding to the natural drivers, population growth can impact water demand either directly (e.g. drinking water consumption) or indirectly through the increased demand for manufactured goods, agricultural products, land etc. Human and economic activities, such as urbanization and land use change, tourism, industry and agriculture, apply pressures on the environment and threaten the quantity as well as the quality of water resources. The cause-effect relations between the anthropogenic drivers and their resulting pressure, expressed as variations in water abstraction and use in the different economic sectors, are not in-depth understood or explicitly analyzed, yet they are very important when it comes to designing effective mitigation measures which should tackle the drivers rather than just the pressures and the impacts. Impacts from drought and water scarcity can be classified as direct or indirect. Reduced crop and forest productivity, increased fire hazard, reduced water levels, increased livestock and wildlife mortality rates, and damage to wildlife and fish habitat are a few examples of direct impacts. Economic losses and social disruption are examples of indirect impacts. In Europe, water scarcity and droughts have affected most economic sectors and various ecosystems. A selection of recent examples is presented in this Chapter touching specific sectors as well as across them.

To assess the state of water availability vs. demand and identify water stress areas, indicators that capture the water balance are a useful and simple tool. Such indicators, bearing different names and definitions, have been developed at global, EU-level, regional or national scales. Under a different context The Water Exploitation Index (WEI), defined as the percentage of the annual freshwater abstraction (both from surface and groundwater) over the long-term available freshwater resources, is a commonly used indicator. For the purposes of the current report and in an effort to formulate a harmonized message for awareness purposes, proxies of the Water Exploitation Index have been calculated at River Basin District scale (supplemented with Country level data to fill gaps). The data used in these calculations have been collected through the various existing reporting streams: the EEA WISE-SoE#3 reporting on Water Quantity, the Eurostat Joint Questionnaire on Inland Waters (JQ IW), the WFD RMPS, the DG ENV MSs Questionnaires supporting the assessment and in-depth reports of the 2007 EU Communication on WS&D. Identifying and characterizing water stress conditions is a complex task as the water scarcity is subject to the spatiotemporal scale of analysis, and its severity relates to the impacts on region and ecosystem Indicators such as the Water Exploitation Index and the recently updated WEI+ can underpin the assessment of water scarcity, although they are subject to limitations and constraints mostly due to their relatively simplified view of the water balance, and thus should be carefully interpreted and supplemented with additional parameters to jointly convey robust conclusions. A detailed discussion on the methodological issues around the selection of water scarcity indicators (relevant parameters, spatial scale, temporal resolution, thresholds etc.) is presented in this Chapter underpinned by relevant examples.

Based on the analysis in this Chapter, it has been identified that data to underpin a solid assessment of water scarcity conditions are still imperfect. The MSs' effort to support these assessments has been significant and many countries have reacted to the EEA call for enhancing the EU water quantity dataflow, but this effort needs to continue and intensify. For the second round of RBMPs, improved water scarcity assessments are also needed on a European level to reflect in water scarcity situations as seen in a river basin. On the regional level, developing adequate management strategies requires for more thorough analysis of the occurrence and causes of water scarcity as a phenomenon that is distinct from droughts. The first round of RBMP reporting showed a deficit in precisely this area, while improving knowledge and governance was the most mentioned group of measures in the

RBMPs. Additional tools are thus needed in order to improve and fortify our ability to characterise and manage water scarcity: blended indicators as satellites to the WEI+, detailed regional water balances (as the core of the analysis) based on harmonised standards, adequate knowledge of ecological flows, regional drought risk maps, etc. The current effort of the EEA Water Asset Accounts has focused on building detailed water balances at a very disaggregated catchment and monltly scale based on MS's data, and suggests that this platform can form a solid basis for the regular calculation and update of any agreed with the MS's indicators of water scarcity and for intercomparison among EU areas.

In **Chapter 3** the concept of vulnerability to water scarcity is analysed. Assessing vulnerability to water scarcity is a complex multi-factor problem. The underlying exposure to stresses and threats may be similar even in quite different conditions, yet vulnerability is influenced by the priorities set, the economic and adaptive capacity of the affected area and population (sensitivity and margin of), the dynamic choices and response strategies adopted. Vulnerability to Water Scarcity and Drought is not yet fully tackled within the scientific community, and recent research has identified the need for a common definition and assessment framework which would support accurate communication and consistent analysis, eliminating ambiguous interpretation. In Europe, although vulnerability to floods has been defined and common risk assessment guidelines have been elaborated (under the EU Floods Directive), no analytical framework has been suggested for WS&D vulnerability. It is indeed true that the fact that WS&D: (a) operates on many scales (spatial and temporal) and levels (moderate to severe), (b) are a complex result of both natural and anthropogenic factors, (c) have a wide variety of impacts affecting many economic sectors, and (d) mitigation is highly dependant on the prevailing socio-economic conditions and adaptive capacity of a system, makes it inherently difficult to frame a single pathway into assessing the nature and degree of vulnerability. Nevertheless, as in all vulnerabilities associated with climate change, key parameters which hold a central role do exist and need to be coherently and scientifically integrated (i.e. exposure, sensitivity, impacts etc.) linking them to a DPSIR framework.

Different cases of vulnerability to water scarcity, for various European areas, are presented as examples in this section with the purpose to rather highlight the diverse contributing factors as well as the strong influence of the prevailing regional conditions that can exacerbate or alleviate its magnitude. The vulnerability clearly relates to the potential (current and future) impacts, the sensitivity and the adaptive capacity of the area in concern. The quantification though of these factors is still challenging since data present limitations, relevant indicators that can represent or proxy the various components are still not clearly defined, while the degree of influence among them (magnitude of their importance) is still to be determined.

Chapter 4 discusses scenarios and projections for water scarcity & drought in Europe. Scenarios provide the means to gain insight into plausible future developments. Rather than providing certain predictions of the future, they can help to gauge uncertainties in order to facilitate decisions that are robust under different possible futures. Scenarios are not forecasts and do not provide likelihoods of how the future might unfold, but can help us understand the uncertainties of future developments and facilitate the development of appropriate future policy response by looking at a wide range of different futures.

Increasing impacts of water scarcity and droughts in the next decades are expected. The likely future occurrence of drought and water scarcity, in terms of intensity and frequency, and the severity of their impacts are dependent on climatic, meteorological, social, environmental and economic factors. Relevant factors to be considered include existing infrastructure, land use, water management practices and institutions as well as public awareness. Analyses of the output of different scenarios can provide us with the bounds of what is probable in the future based on a combination of different variables consistent with our knowledge of the climate system and land use changes. Using scenarios helps to imagine what might happen and is therefore an important method for flexible mid-term and long-term planning.

Climate scenarios provide the necessary input to make projections of changes in water scarcity and drought location, frequency and severity. By assuming different emissions scenarios and using different GCMs alongside different methods of downscaling, most climate model outputs point to a likely increase in temperatures over land in Europe. Higher temperatures lead to higher evaporation and more intense and frequent heat waves. Precipitation is likely to increase on a global scale, but there is considerable divergence and uncertainty at the local scale. At the same time decreases in ice and snow are evident in Europe. A number of EU projects have focused on improving the projections of climate change, the quantification of uncertainties, and the implications of projections in terms of adaptation and mitigation. Recent studies suggest that climate change will likely lead to an increase of the frequency and severity of droughts at the global level, but there are significant regional differences. More severe and persistent droughts will be experienced in most parts of Europe in the frost-free season by the end of this century, but drought conditions will be of less importance under future climate conditions in the frost season in most northern and north-eastern regions. This calls for a management approach that learns from past developments and considers likely future developments. Knowledge of the spatial and temporal occurrence as well as potential severity is crucial for appropriate management responses.

Evaluating likely future water scarcity is more complex as it also involves evaluating likely future water use, which is a function of a number of social, economic and environmental factors. Projecting water scarcity is a complex exercise with a wide range of uncertainties, particularly arising from the development of different socio-economic futures. Given the results of different scenarios and storylines, social systems and future policies will alter the natural impacts projected by the climate scenarios. Several projects (SCENES, ClimWatAdapt) assessed future water stress conditions based on plausible storylines built on the GEO4 scenarios, evolving along two axes, having a more global or regional orientation, and a more environmental or economical focus. Results suggest that water withdrawals (as a result of future water use driven by socio-economic and technological changes) are expected to increase in Europe by 2050 under the Economy First scenario with the exception of river basins in Denmark, the Iberian Peninsula, Italy, Greece, Cyprus, and Turkey, while for the Sustainability Evantually scenario a decrease in total water withdrawals of more than 25% is simulated for all of Europe. The main reason leading to this decline in total water withdrawals are technological innovations designed to use water more efficiently as well as an increasing commitment to conserve water.

The analysis of scenarios provides us with information that facilitates target setting and the definition and subsequent implementation of policies. Future water scarcity and drought scenarios need to take into account though the uncertainties of the projections since any scenario analysis can not be free of uncertainty. Uncertainty sources include possible error in the baseline assumptions, which relate to the use of different climate models, to bias introduced by the downscaling methods and techniques, to bias associated with the hydrological modelling and parameterisation, and the inherent uncertainty of the “forecasted response” that society is anticipated to have. Considering that water scarcity and drought have implications on numerous socio-economic sectors and ecosystems, as well as the cross-cutting nature of these phenomena, implies that any policy response can benefit when assessing its robustness and sensitivity against a range of possible futures. Despite uncertainties and the wide range of different approaches, state-of-the-art models and tools used to study and evaluate likely future water availability and water use have been proven robust enough as past predictions can now be validated in the recent trend analyses, and can at least provide a realistic enough range of the best and worst-case developments. Efforts on improving scenario building and minimising the associated uncertainty should progress, strongly engaging though various stakeholders throughout the process of interpretation, development, and validation since the scenarios need to be tailored to the regional reality of Europe.

Finally, **Chapter 5** discusses adaptation policies and measures and the progress in their implementation under EU policy context, while touching on future needs towards a risk management approach.

The European Commission recently determined that droughts in Europe have cost the economy 100 billion € over the last 30 years. The 2010 European Council conclusions on water scarcity, drought and adaptation to climate change recognised the eminent problem. Considering that the likelihood of this situation is increasing due to climate change, the European Council urged Member States to elaborate water scarcity and drought management plans (WSDMPs). Developing appropriate programmes of measures that facilitate adaptation to water scarcity and drought in Europe is challenging due to the diversity of economic, social, environmental conditions and the wide range of situations where these are to be applied.

At European level, in the area of water scarcity and drought, no distinct directive provides a management framework. The WFD is not directly designed to directly address quantitative water issues. The EC Communication "Addressing the challenge of water scarcity and droughts in the European Union is the primary policy document guiding EU Member States' efforts to combat water scarcity and drought. The Communication identifies seven policy options (pillars) for tackling water scarcity and drought issues: water pricing, more efficient water allocation, improving drought risk management, considering additional water supply infrastructures, fostering water efficient technologies and practices, contribute to the development of a water-saving culture in Europe, improve knowledge and data collection. The assessment of the implementation of these policies is evaluated in periodic follow-up reports, the latest of which was published in 2011 evaluating the progress achieved in 2010. This report concluded that water scarcity and drought is not only a problem in Mediterranean countries but also in many other European countries. Numerous challenges are making the attainment of the WFD objectives difficult, and the EU response to the various prevailing issues has been elaborated in the recently published Communication "A Blueprint to Safeguard Europe's Water Resources". The Blueprint aims to tackle the obstacles which hamper action to safeguard Europe's water resources. It is based on an evaluation of the existing policy, on a wealth of information and analysis (including the assessment of the Member States River Basin Management Plans – RBMPs), and on extensive public consultations, yet does not propose any one size fits all solution, in line with the principle of subsidiarity and recognizing that the aquatic environments differ greatly across the EU. The key themes addressed include: improving land use, addressing water pollution, increasing water efficiency and resilience, and improving governance by those involved in managing water resources. The main building blocks in relation to the WS&D policy review are, in addition to the improvement of water allocation based on ecological flow, water efficiency, adequate implementation of instruments and policies which provide incentives for water efficiency, water pricing with metering as a precondition, as well as cost-recovery (including environmental and resource costs) for water services taking into account the polluter pays principle and better planning. In the case of the latter, this is proposed through demand management, land use planning, the development of better information and indicators, policy integration and planning for emergency preparedness and response.

When considering adaptation measures to address water scarcity and drought issues, demand-side management has a great potential. There are, however, numerous challenges regarding possible future conflicts between water users, environmentally harmful subsidies, controlling illegal abstractions, designing and enforcing tight accountability, measuring and water licensing mechanisms. These are gradually being discovered and addressed. In order for demand reduction adaptation to become a viable solution, cooperation is a key factor and requires appropriate institutional frameworks in order to secure that water users "play by the rules". This does not only require enforcement; public participation and awareness are even greater priorities in order to ensure that the threats to water resources are understood and appreciated. This makes adaptation to less water a universal problem, which, if it is to be overcome, will require cooperation from all levels of society.

Supply side adaptation measures are already common practice in arid regions and other areas affected by water scarcity and drought and there is increased interest in extending these methods to other regions where the potential to harness waste, grey or rain water is high. The cost and information dissemination will likely be the greatest challenges faced by users wishing to implement desalination or water recycling programmes. Yet, it is clear that they shouldn't be a priority and that we should resort to them only under specific circumstances. As demand management alternatives fit better with climate adaptation, work with nature instead of against it, and provide a lot of space for innovation, they must be prioritised in managing and mitigating water scarcity and drought, while increase supply measures should only be brought in if the former cannot resolve the problems in hand.

Having realised the high economic, social and environmental cost of inaction regarding water scarcity and drought, and the likely worsening under climate change, the importance of identifying and implementing concrete adaptation actions has been recognised. The cost implications and the possible tensions surrounding water resources and the implementation of adaptation measures have been identified as stumbling blocks to rapid advancement. However, commitment and prioritisation by the European community is encouraging to future developments, and progress is made towards adopting a more integrated risk-oriented approach as opposed to a reactive crisis management approach. A risk management approach entails the correct identification of the current and future risk, at the appropriate spatial and temporal resolution, defined as the combined effect of the hazard and vulnerability, the latest being associated with the exposure, sensitivity, and resilience of the physical and socio-economic system. The identification, prioritisation and quantification of all the components which constitute elements of the ecosystems' vulnerability to water scarcity and drought are highly challenging. Finding a representative methodology to analyse the cause-effect relations of all the above factors and their combined effect as the "total risk" is still weakly investigated.

Science-policy interfacing is a crucial aspect that can help improving Europe's resilience to water scarcity and drought phenomena. A tight interaction between the policy makers, the stakeholders who draft the research agendas, and the researchers is important and beneficial for all parties, i.e. the research community can tune their focus on research priorities tailored to policy needs and real-life problems and thus of greater impact to the society, while the policy community has in their hands really applicable tools which can support decision making at various scales. Progress towards adopting risk-management approaches to combat drought and water scarcity is evident, and efforts to improve Europe's water resilience are ongoing. Yet, further developments are necessary to fortress our ecosystems, as well are the society, against these hazards, and if we want to successfully implement concrete and integrated solution researchers, policy-makers and practitioners need to convene in a think-tank to share information and experiences, identify critical knowledge gaps, exchange face-to-face on best practices for drought and water scarcity risk reduction and guide the future development based on real-life needs.

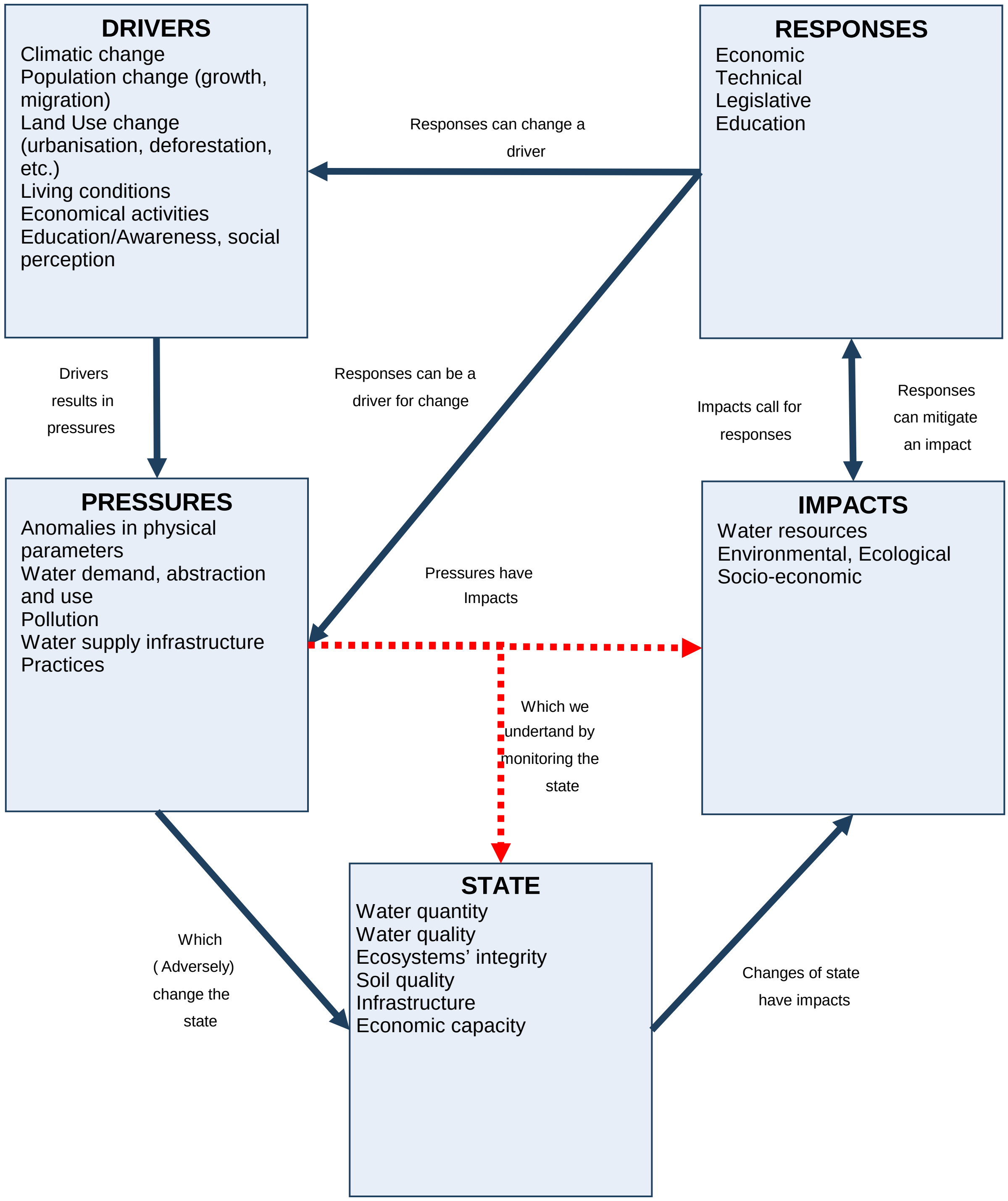
1 Introduction

Water scarcity occurs where there are insufficient water resources to satisfy long-term average requirements. It refers to long-term water imbalances, combining low water availability with a level of water demand exceeding the supply capacity of the natural system. Although water scarcity often happens in areas with low rainfall, human activities exacerbate the problem, in particular in areas with high population density, tourist inflow, intensive agriculture and water demanding industries. In the near future, it is likely that predicted climate change will aggravate this situation in the most water scarce parts of southern Europe, but could also affect areas which do not currently face such problems. A combination of less precipitation and higher temperatures can reduce the amount of available water and resulting economic impacts may be significant, affecting several sectors: agriculture, forestry, energy, and drinking water supply. Activities that depend on high water abstraction and use, such as irrigated agriculture, hydropower generation and use of cooling water, will be affected by the changed flow regimes, the reduced annual water availability and the altered seasonal distributions of this water. A reduction in the amount of surface and groundwater may have huge environmental impacts. These impacts could range from too little water in rivers and lakes to achieve good status and the drying out of wetlands, to the intrusion of salt-water into aquifers and less water to dilute inputs of pollutants. As demand for water increases due to the rise in population and modern lifestyle, the future vulnerability will be further exacerbated with multiple socio-economic implications (yield reductions, cost of mitigation measures, conflicts among users, social equity and disturbance due to quotas and restrictions etc.).

In view of the problem, the European Commissions has issued in 2007 a Communication on Water Scarcity and Droughts (EC, 2007a), setting seven specific pillars, such as putting the right price tag on water, fostering water efficient technologies and practices, improving drought risk management, enhancing a water-saving culture, improving knowledge and data collection, etc., and proposing a way forward. Follow-up reports of this Communication, assessing the advancement of the individual Member States and of the EU as a whole, have been issued annually (EC, 2012a), while a fitness check of the action and new policy recommendations have been launched in the 2012 EC Communication “A Blueprint to Safeguard Europe's Water Resources Blueprint” (EC, 2012b). Clearly, responses and adaptation measures differ, depending on the issues and priorities faced in each region. Demand management oriented measures are necessary for future sustainability and allow for adaptation to climate change. Nevertheless, supply management will be needed in some cases. In general, the response measures can be classified under four main categories: economical (e.g. water pricing, cap and trade, taxes, etc.), technical (e.g. leakage reduction, water saving installations, metering, monitoring, re-use facilities), legislative (consumption quota, policy), educational (e.g. raising awareness, promoting water saving culture). The effectiveness of the response measures is difficult to assess, as it relates to the inherent complexity of the water scarcity phenomenon, which has its roots both on natural and anthropogenic drivers, which in turn result in pressures, adversely changing the state and causing multiple impacts on the environment, economy and society. This interplay of natural and socio-economic factors, as illustrated under the Drivers-Pressure-State-Impact-Response (DPSIR) framework (Figure 1.1), and their cause-effect relations are still poorly understood, thus challenging our assessment of water scarcity vulnerability and associated risk.

Traditionally, most attempts to manage drought and water scarcity and their related impacts focused on a rather reactive crisis management approach resulting thus in being ineffective, untimely and unsustainable in the long term. Currently there is a tendency to move forward on a proactive risk management approach in order to increase the resilience and sustainability of the affected regions. This transition from crisis to risk management is challenging since governments and individuals are accustomed to a reactive approach and little institutional capacity exists in many European countries for altering this behavior. The current report attempts to improve our current knowledge, by quantifying water scarcity and drought phenomena across Europe, presenting the main drivers and pressures, illustrating the various impacts experienced by the Member States, addressing key issues of vulnerability, while presenting selected adaptation policies and measures and various scenarios. A selection of case studies is also presented in order to better illustrate the vulnerability of the different sectors and environments to water scarcity and drought.

Figure 1.1 Assessing WS&D under the DPSIR framework approach



Source: Kossida et al., 2009 (modified)

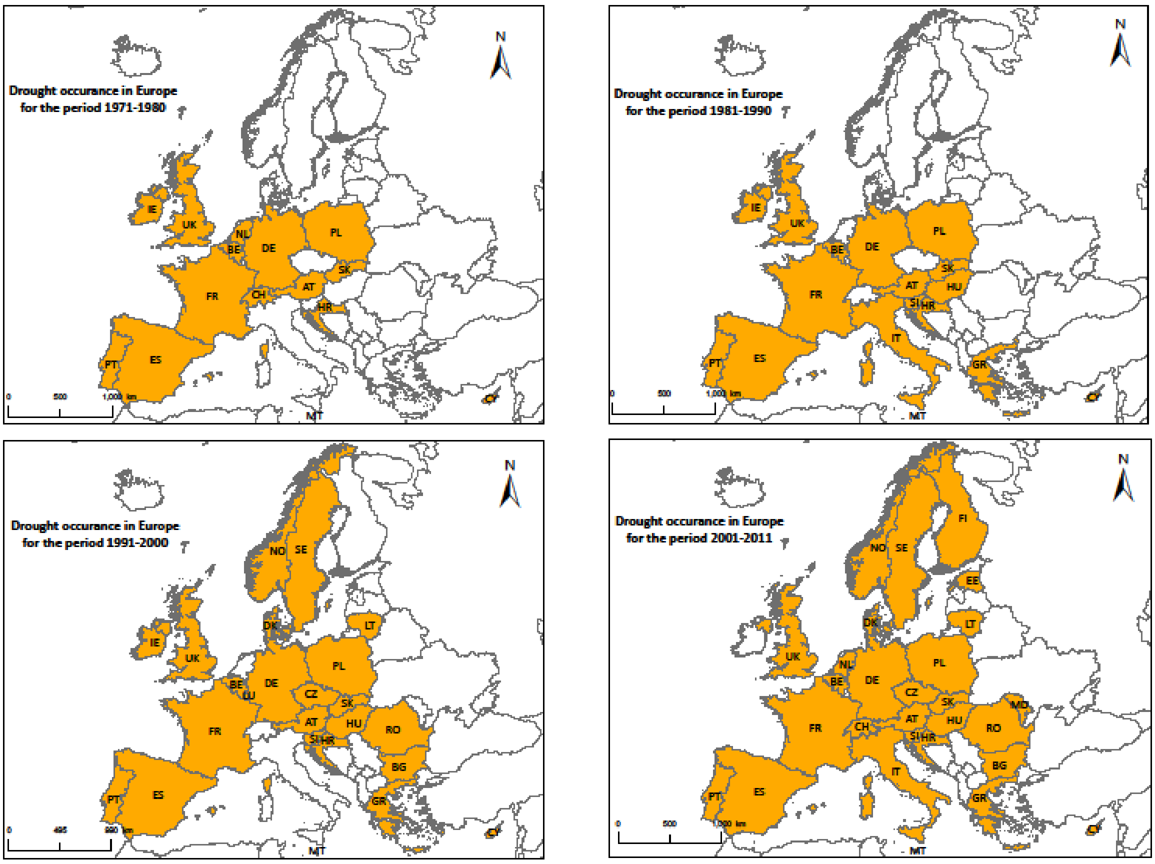
2 Quantifying water stress across Europe

2.1 *Drought and Water Scarcity occurrence in Europe (current and past conditions)*

Drought episodes in Europe

Many European countries have experienced drought episodes of various significance (ranging from less to more severe), duration (a few months to years) and extend (local to regional to national) in the past 40 years. Drought has often propagated from a meteorological hazard to an agricultural, hydrological and socio-economic, subject to the regional characteristics, and has (depending on the adoptive capacity of the affected communities) adversely impacted both the environment and the society. Map 2.1 illustrates the geographical extend of observed drought episodes in Europe from 1971–2011.

Map 2.1 Observed drought episodes in Europe from 1971–2011

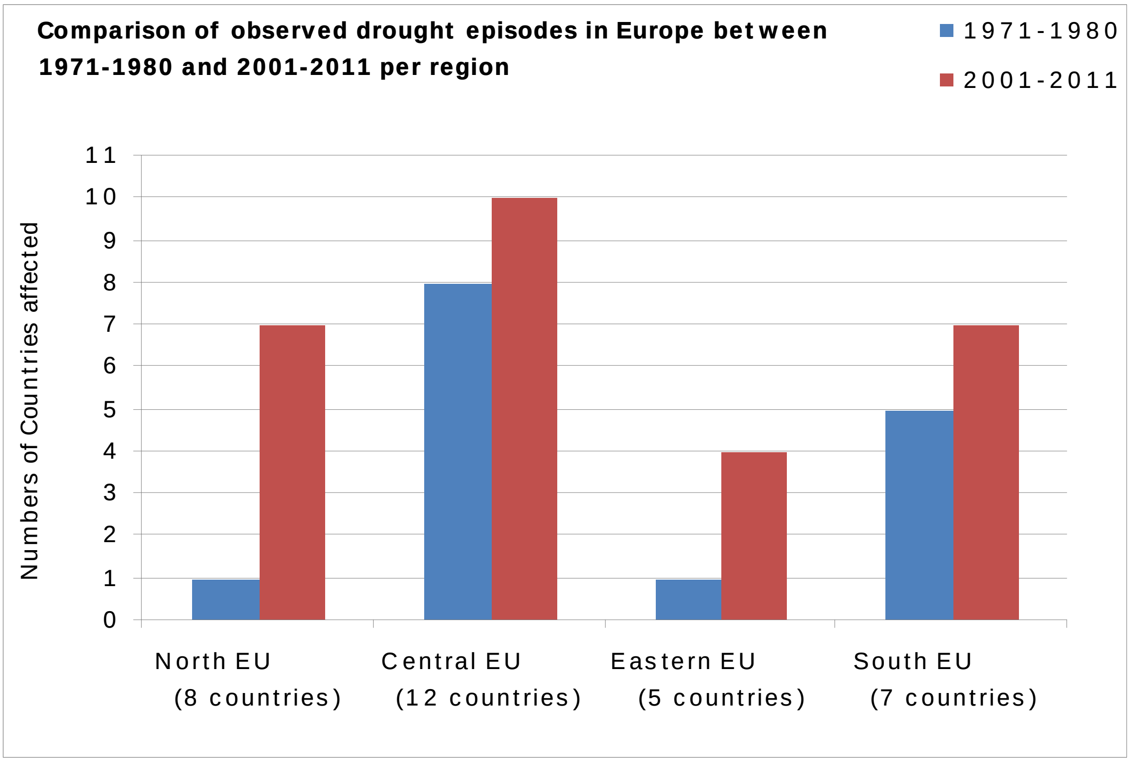


Note: A country is coloured with orange if drought episodes have occurred in that country during the reference decade, regardless of their temporal and spatial (local or nationwide) scale. No distinction between the severity, the frequency and the extent of the events is made. It is recognised that this is a simple representation based on MSs' identification and is not based on an in-depth analysis based on harmonised criteria and indicators.

Source: Compiled by the authors based on multiple data sources (country reports, scientific papers, SoE assessments, DG ENV questionnaires, etc.)

The background information has been collected from numerous sources (e.g. country reports, scientific papers, SoE assessments, DG ENV questionnaires etc.) and was collated to produce maps per decade. It must be emphasized that these maps demonstrate drought episodes occurred in a country during the reference decade regardless of their temporal (few months or years) and spatial (local or nationwide) scale. We can observe an increase in the number of countries affected by drought per decade, rising from 15 in the period 1971-1980 to 28 in the period 2001-2011. A further comparison between the periods 1971-80 and 2001-11 per region (North, Central, Eastern, South EU) clearly shows that drought occurrence has significantly increased in the period 2001-11, not only in the South and Central EU, but also reaching now the North and Eastern EU (Figure 2.1). The year when most countries were affected (18 in total) was 2003, followed by 2006 (14 countries), 1992 (13countries), 1995 (12 countries) and 2005, 1990, 1989 (11 countries).

Figure 2.1 Comparison of the number of countries affected by drought episodes (per region) between 1971-1980 and 2001–2011

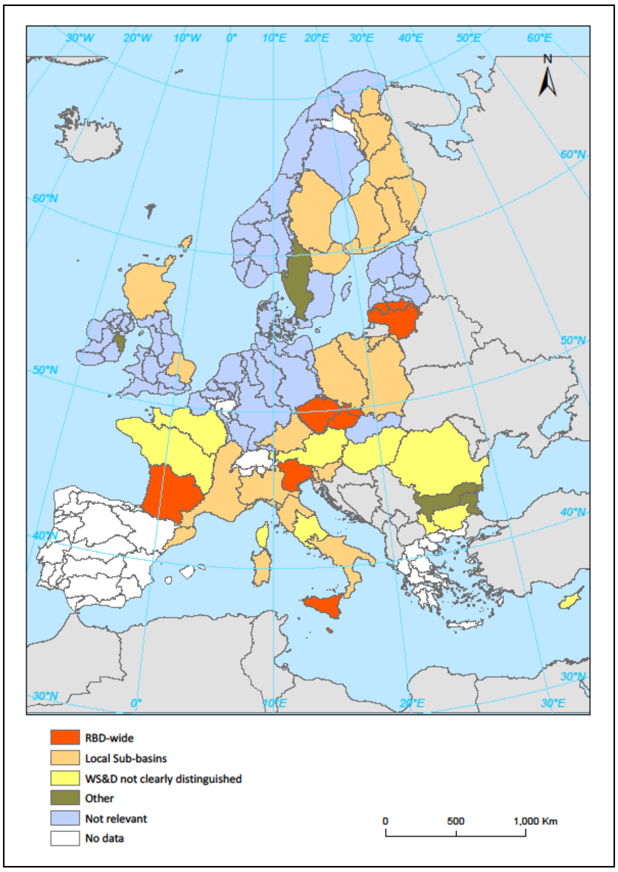


Notes: North EU: Denmark, Estonia, Finland, Latvia, Lithuania, Norway, Sweden, United Kingdom. Central EU: Austria, Belgium, Czech Republic, Germany, Hungary, Ireland, Luxembourg, Poland, Slovakia, Slovenia, Switzerland, Netherlands. Eastern EU: Bosnia & Herzegovina, Bulgaria, Croatia, Moldova, Romania. South EU: Cyprus, France, Greece, Italy, Malta, Portugal, Spain.

Source: Compiled by the authors based on multiple data sources (country reports, scientific papers, SoE assessments, etc.)

Other sources for information are the RBMPs. Droughts are reported in a wide range of RDBs in different parts of Europe. Drought spells are recognised either as RBD-wide phenomena or as local phenomena affecting parts of the entire basin (Map 2.2). However, it is not always possible to distinguish between droughts and water scarcity in the reporting (Schmidt et al., 2012). As several of the RBMPs were not published at the time of the analysis, including some Mediterranean countries, the absolute numbers are of less relevance. But the analysis of the RBPMs clearly indicates that droughts are not only characteristic for river basin districts in Southern Europe and occur in many regions across the EU (Schmidt, 2012).

Map 2.2 Occurrence of drought as identified in the WFD RBMPs



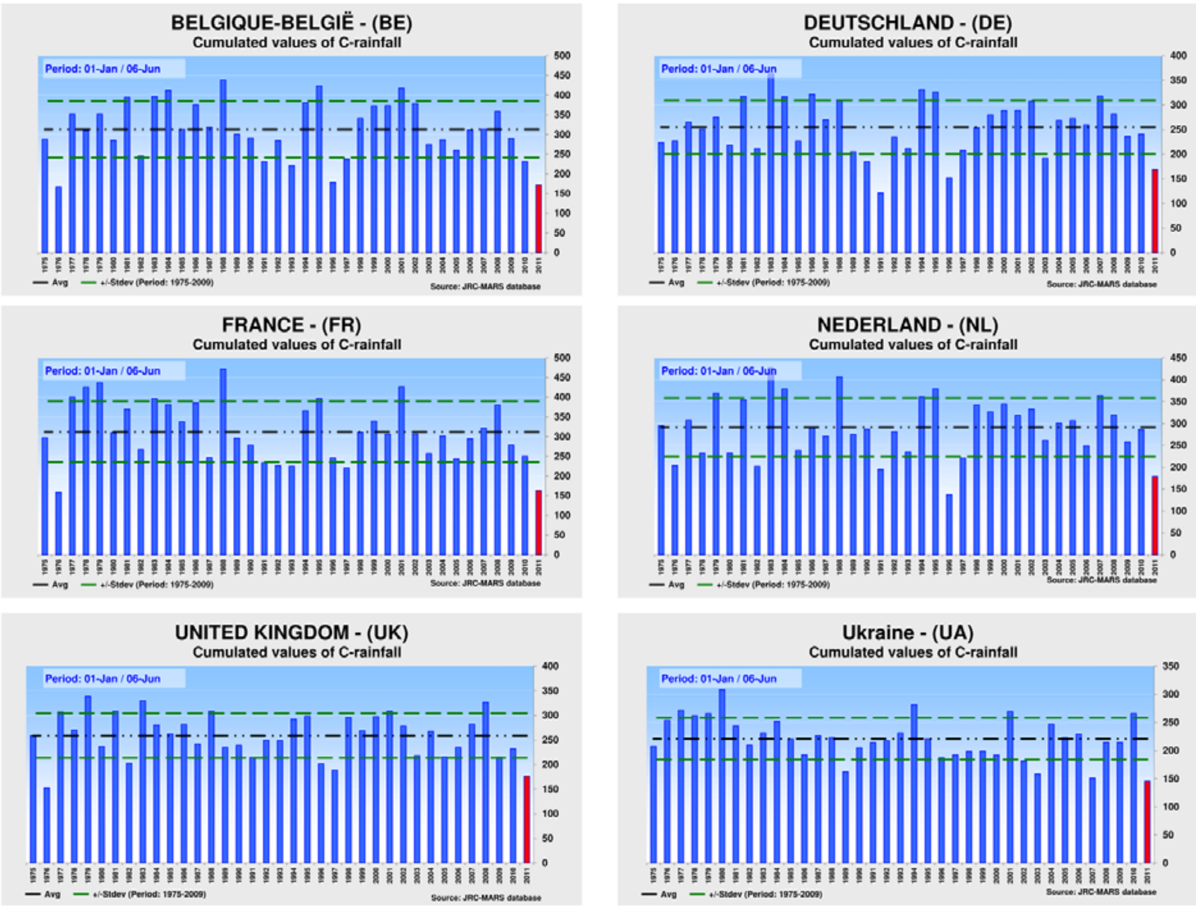
Notes: “Other” also includes the cases where there is no clear information about these issues in the RBMPs.

Source: Schmidt and Benítez, 2012, based on data assessed through the WFD RBMPs.

Information on recent drought occurrence at EU level can be obtained through the European Drought Observatory (EDO) and is based on a combination of indicators, namely the Standard Precipitation Index (SPI), the Soil Moisture Anomaly and the Fraction of Absorbed Photosynthetically Active Radiation (FAPAR). During 2011, in the period January to April, severe cumulated rain deficits were recorded in France (where 2011 is the driest year since 1975), England, Belgium, The Netherlands, Germany (Rheinland-Pfalz, Schleswig-Holstein, Niedersachsen, Thüringen), Denmark, Czech Republic (Stredocesky kraj, Severovychod), Slovakia (Vychodne Slovensko, Stredne Slovensko), almost all of Hungary and locally in Austria, Slovenia and Croatia (JRC, 2011a). These drought conditions continued into May 2011, with northern England, Wales, central-southern England, Denmark, northern Germany, central parts of the Ukraine and the western half of France experiencing a persistent shortage of 12-months of rainfall (based on the Standard Precipitation Index SPI-12) with possible impacts on reservoir storage levels in these regions (JRC, 2011b). The cumulative rain deficits recorded from January to June 2011 compare to historim minima for many countries (Figure 2.2): in France (comparable to 1976), England (comparable to 1997), Belgium, The Netherlands (comparable to 1991, 1982, 1976), Germany (comparable to 1996), Denmark, parts of the Czech Republic and Slovakia, almost all of Hungary, locally in Austria, Slovenia and Croatia, Ukraine (absolute minimum since 1975), Belarus and the Baltic countries (JRC, 2011b). For all six countries in Figure 2.2 the accumulated rainfall in the first half of 2011 is lower than the rainfall average minus one standard deviation for the first half of the year and in the top 3 of the years with the lowest rainfall over the first 6 months of the year in more than 35 years.

Reduced rainfall, below the standard expected amount, has occurred during the winter months of 2012 over extended parts of Southern (Iberian peninsula, South France, North Italy) and Western Europe, which in some cases (central Spain, England, western France) evolved into a prolonged dry spell with 6-month and 12-month rainfall totals being categorised as severely or extremely dry (according to the SPI-6 and SPI-12 indicators compiled by the European Drought Observatory-EDO) (JRC, 2012). Based on the daily soil moisture anomaly indicator the drought impacted Spain, Portugal, Southern France, Central Italy, Greece (locally), Hungary, Bulgaria and Romania, with affected areas also evident in Denmark, North Italy (Po river) and the Northern UK (JRC, 2012). Figure 2.3 below presents snap-shots of drought conditions in Europe as calculated by the European Drought Observatory (EDO) using the Combined Drought Indicator, based on SPI, soil moisture and fAPAR. There are three classification levels: watch (when a relevant precipitation shortage is observed), warning (when the precipitation translates into a soil moisture anomaly) and alert (when these two conditions are accompanied by an anomaly in the vegetation condition).

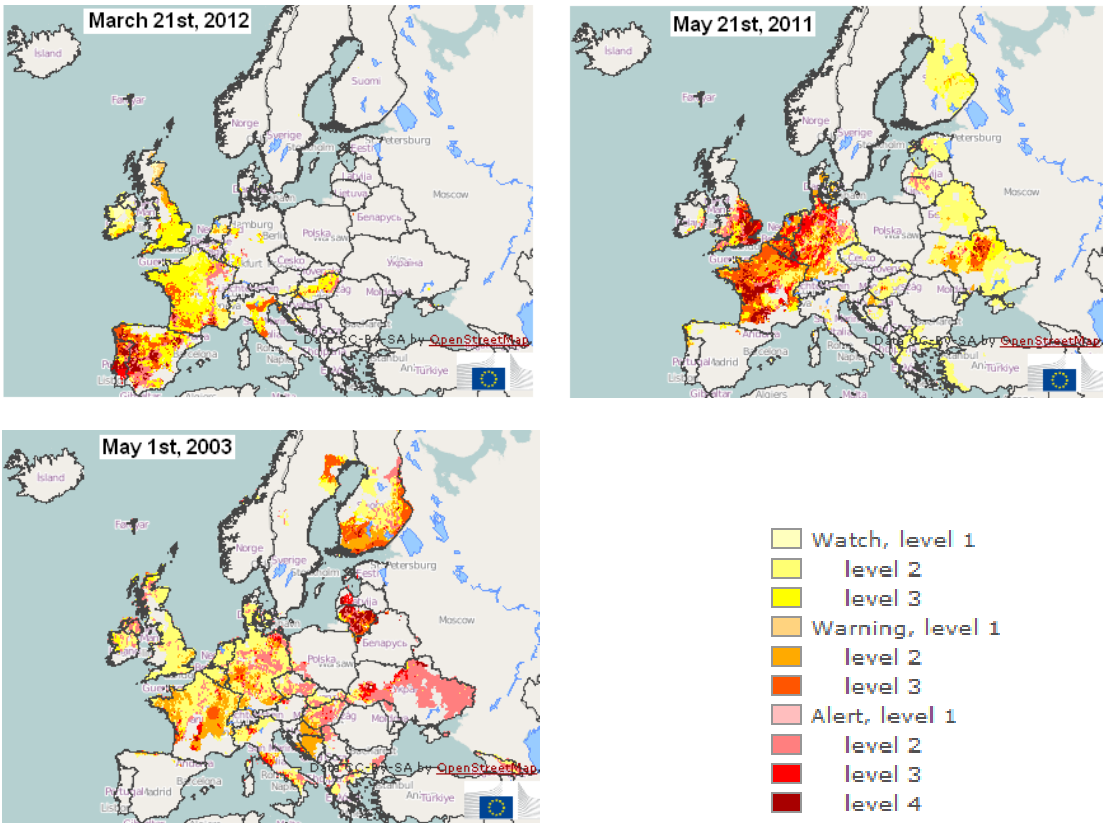
Figure 2.2 Accumulated rainfall for 1st of January to 6th of June 2011



Note: Comparison of accumulated rainfall for 1st of January to 6th of June 2011 with the historic time series 1975 to 2010 (01/01 until 30/06 of every year). 2011 is highlighted in red. Black dot-dashed line: Average rainfall 1975-2010, green dashed lines: One standard deviation above and below the average (1975-2010).

Source: JRC, 2011b.

Figure 2.3 Mapping of drought conditions in Europe as calculated by the Combined Drought Indicator (based on SPI, soil moisture and fAPAR)



Notes: Mapping of drought conditions in Europe as calculated by the Combined Drought Indicator (based on SPI, soil moisture and fAPAR) for top left March 21st 2012, top right May 21st 2012, and bottom left May 1st, 2003 known as a dry year for large parts of Europe.
There are three classification levels: watch (when a relevant precipitation shortage is observed), warning (when the precipitation translates into a soil moisture anomaly), alert (when these two conditions are accompanied by an anomaly in the vegetation condition).

Source: European Drought Observatory (EDO), Joint Research Centre, European Commission.

Water scarcity conditions in Europe

Water Scarcity, results from an imbalance between water availability, in the broader sense (physical related to the water cycle, and technical related to water infrastructure), and water demand, for a series of activities. Water Scarcity is thus at the crossroads between environmental phenomena (in the form of drought) and social phenomena (in the form of water demand – either directly or indirectly). At least 11% of the European population and 17% of its territory have been affected by water scarcity to date (EC, 2007a).

To assess the state of water availability vs. demand and to identify water stress areas, indicators that capture the water balance are a useful simple tool. Such indicators, bearing different names and definitions, have been developed at global, EU-level, regional or national scales under different context as presented in Table 2.1.

Table 2.1 Indicators relevant to water scarcity and stress, developed by the EU and other initiatives

Indicator/ Index	Reference	Spatial Scale	Context	Required Data
Water Exploitation Index (WEI)	EEA, 2010	Country, some RBs	Annual freshwater abstraction as percentage on long term freshwater resources availability is calculated. 20% and 40% are the relevant thresholds for water stress and extreme water stress respectively	Annual freshwater abstractions, long term annual freshwater resources availability (LTAA)
Water Exploitation Index+ (WEI+)	Faergemann , H. 2012; EG WSD work in progress)	RBD, RB	Net abstraction (abstraction minus return) is calculated as a percentage of the renewable water resources.	Freshwater abstraction, renewable water resources, availability, returns (monthly, annual temporal scale)
Intensity of use of water resources	OECD, 2003	country, region	Ratio of abstraction over available freshwater resources	Annual freshwater abstractions, total renewable water resources
Exploitation index of renewable resources	Margat., J, Plan Bleu, 2004	country	This indicator measures the relative pressure of annual withdrawals of renewable natural freshwater resources, including transport loss. The resources of each country are defined by the surface or underground water streams which already exist or are entering in the territory	Annual abstraction, available water calculated over the medium to long term (30 years).
Vulnerability of Water Systems	Gleick, 1990	watershed	It describes the vulnerability of water resources systems based on the five criteria and corresponding thresholds: storage volume relative to total renewable water resources, consumptive use relative to total renewable water resources, proportion of hydroelectricity relative to total electricity, groundwater overdraft relative to total groundwater withdrawals, variability of flow (calculated by dividing the surface runoff exceeded only 5% of the time by the quantity exceeded 95% of the time). These five indicators (relevant thresholds are set for each one) are not aggregated to an overall index but for each region the number of vulnerable sections is presented. This approach emphasises the sectors of watersheds that are threatened. Relevant thresholds are set for each indicators	Storage volume (of dams), total renewable water resources, consumptive use, proportion of hydroelectricity to total electricity, groundwater withdrawals, groundwater resources, time-series of surface runoff
Water Resources Vulnerability Index (WRVI)	Raskin, 1997	country	Total annual of withdrawals as a percent of available water resources	Annual water withdrawals, total renewable water resources

Indicator/ Index	Reference	Spatial Scale	Context	Required Data
Indicator of water scarcity	Heap et al., 1998	country, region	It is defined by the intensity of use of water resources, i.e. the gross freshwater abstractions as a percentage of the total renewable water resources or as a percentage of internal water resources. The variable of desalinated water resources is included 9,as a deduction from the abstraction). The annual available water which is calculated by the internal water resources in the country, plus the amount of external water resources corrected by the ratio of the external water resources that can be used (this ratio is influenced by the quality of the transboundary water, the real consumption of water resources in the upstream region, and the accessibility of water)	Annual freshwater abstractions, desalinated water resources, internal renewable water resources, external renewable water resources, ratio of the ERWR that can be used
Water availability index WAI	Meigh et al., 1998	region	The index compares the total demand (from all sectors) to the total surface water (calculated as the 90% reliable runoff) and groundwater resources (estimated either as the potential recharge that is calculated from the monthly surface water balance, or as the potential aquifer yield). The month with the maximum deficit or minimum surplus respectively is decisive.	Time-series of surface runoff (monthly), time-series of groundwater resources (monthly), water demands of domestic, agricultural and industrial sector
Water Poverty Index (WPI)	Sullivan, 2000, 2002	country, region	This index tries to show the connection between water scarcity issues and socio-economic aspects. It ranks countries according to the provision of water, combining five components. Each of these components is derived from two to five indicators which are normalised to a scale from 0 to 1.	Internal renewable water resources, external renewable water resources, access to safe water, access to sanitation, irrigated land, total arable land, total area, GDP per capita, under-5 mortality rate, UNDP education index, Gini coefficient, domestic water use per capita, GDP per sector, Water quality variables, use of pesticides Environmental data (ESI)

Indicator/ Index	Reference	Spatial Scale	Context	Required Data
IWMI indicator of water scarcity	Seckler at al. 1998	country	The IWMI analysis takes into account the share of the renewable water resources available for human needs (accounting for existing water infrastructure), the primary water supply. Its analysis of demands is based on consumptive use and the remainder of water withdrawn is accounted for as return flows. A country is defined to be absolutely water-scarce if the demand is more than 50% of the available water resources. Seckler et al. then analysed, the future adaptive capacity, primarily through an assessment of potential development of infrastructure and an increase of irrigation efficiency through improved water management policies. Countries that will not be able to meet the estimated water demands in 2025, even after accounting for future adaptive capacity, are called "physically water scarce". Countries that have sufficient renewable resources, but would have to make very significant investment in water infrastructure to make these resources available to people, are defined as "economically water scarce".	IIWMI1 = withdrawal as a % of water supply IIWMI2 = Future withdrawals as a % of current withdrawals
Water Stress Index (WSI) per source	European Water Partnership, 2010a; 2010b	Site specific	Two sub-indicators calculated as the percentages of collective water abstraction and collective water consumption in relation to the available water per source respectively. Consideration is made whether the operation is a major abstractor (water withdrawals that account for an average of 5% or more of the renewable freshwater resources) or a minor abstractor (water withdrawals < 5% of the renewable freshwater resources).	Water abstraction/ consumption as the percentage of available water per source (%) with the water abstraction volume per source in [m^3/month or sensitive period] and average [m^3/year]
Water discharge index (WDI)	European Water Partnership, 2010a; 2010b	Site specific	The water discharge of the production site is calculated and evaluated by the ratio in % of the discharged water over the total water abstraction by the operation. The water steward is a "minor contributor" when discharged water accounts for only 20-40% of the water abstracted, and a "major contributor" when it accounts for 40-60% of the water abstracted.	Total amount of water discharge [m^3/time period] in relation to total amount of available water body [m^3/time period]

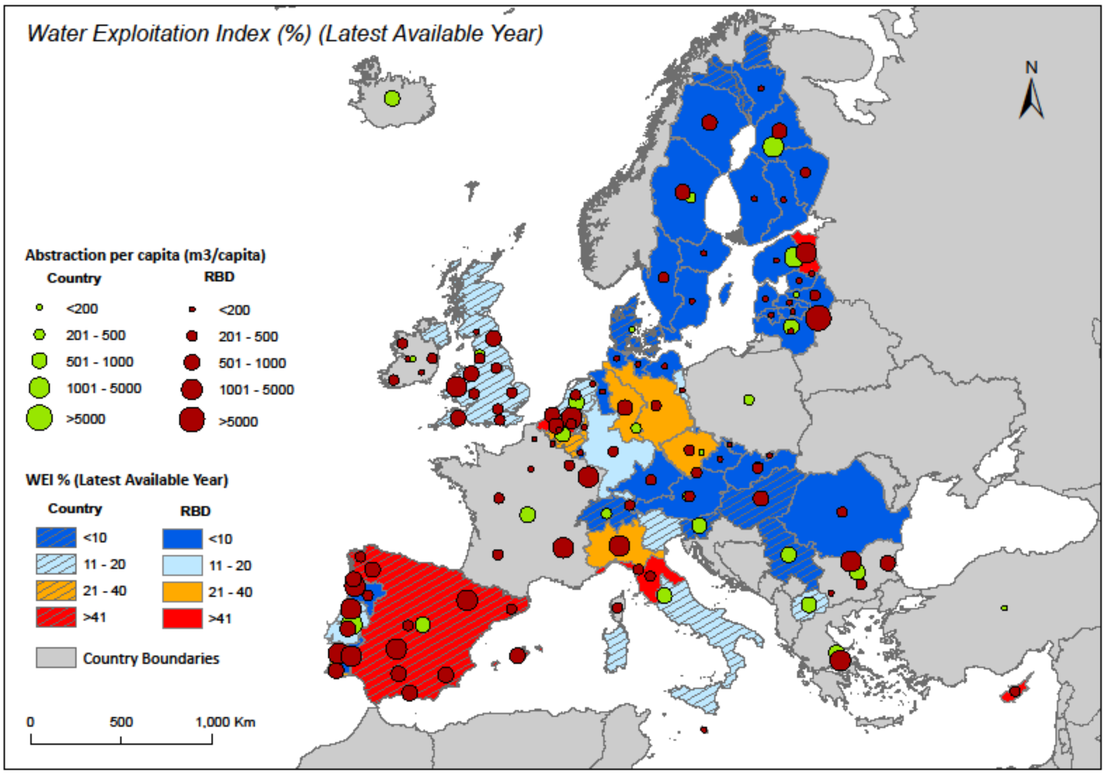
The Water Exploitation Index (WEI) has been defined as the percentage of the annual freshwater abstraction (both from surface and groundwater) over the long-term available freshwater resources. WEI has been traditionally applied at country scale to map the level of pressure (stress) that human activity (i.e. abstraction) exerts on the natural water resources. It is however identified that its temporal and spatial resolution do not allow for a proper characterisation of the prevailing state as regional stress conditions may be leveraged when calculated at these highly aggregated temporal and spatial scales. Work towards improving the WEI and refining it into an updated WEI+ has been undertaken within the WFD Common Implementation Strategy (CIS) Expert Group on Water Scarcity and Drought (EG WSD). The WEI+[1] proposes a calculation at annual and monthly (where relevant) steps, at River Basin District or River Basin scale, while redefining the calculation of the renewable water resources and accounting for returned water as a component which alleviates part of the environmental pressure. The work is in progress, and although significant improvements have been achieved it still remains a challenge to find common metrics and relevant thresholds for this indicator so that it accurately communicates a validated classification of the degree of water scarcity across the EU River Basins.

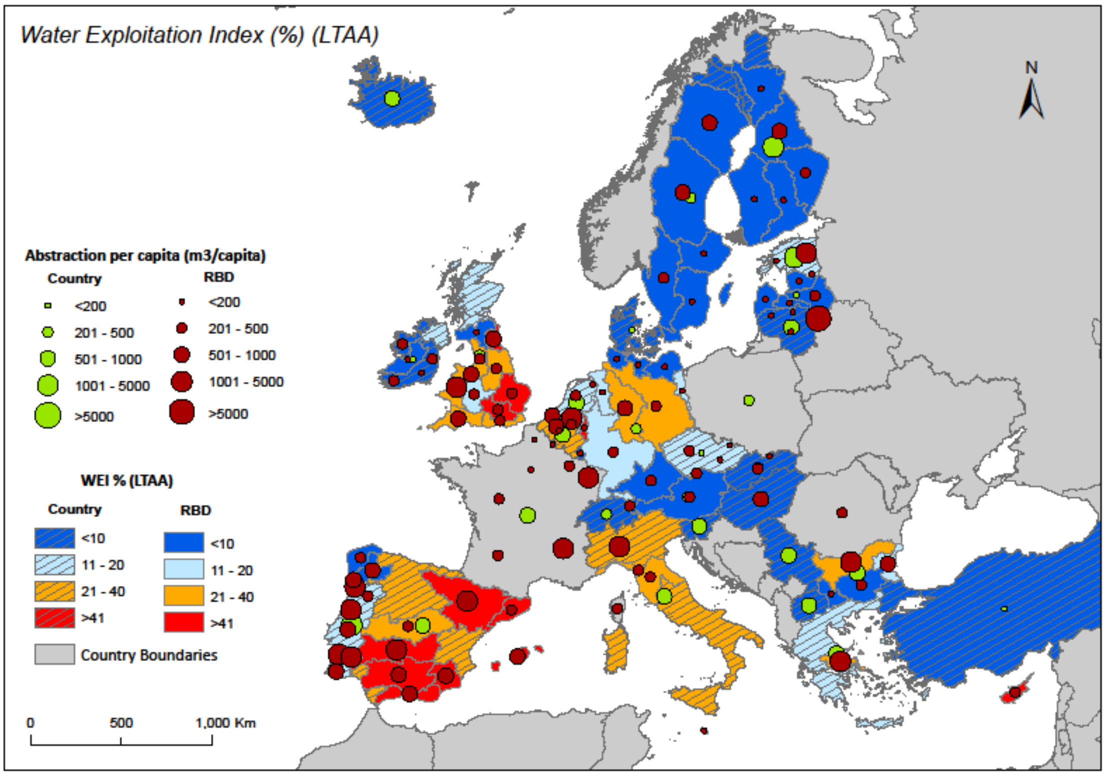
For the purposes of the current report, in an effort to formulate a harmonized message for awareness purposes on the state of the water resources and to provide an EU overview of water stress conditions, proxies of the Water Exploitation Index have been calculated, embedding to the best degree possible many of the new elements of the WEI+. This assessment is also meant to provide a hot spot analysis, and to be able to communicate the problem of overexploitation to other EU policy areas and the general public, The data used in these calculations (Map 2.3, Map 2.4) have been collected through the various existing reporting streams: the EEA WISE-SoE#3 reporting on Water Quantity, the Eurostat Joint Questionnaire on Inland Waters (JQ IW), the WFD RMPS, the DG ENV MSs' Questionnaires supporting the assessment and in-depth reports of the 2007 EU Communication on WS&D. Missing data have been, where properly, supplemented with data form official national web sources. All data and results have been presented to the EIONET Network, the 2012 State of water stakeholder and Eionet Workshop (29-30 March 2012, Copenhagen) and the EG WSD, and have been open for 2 consultation rounds with the Member States (MSs) (February-April 2012, July-August 2012). Feedback and corrections from the MSs have been incorporated. The resulting calculations are presented in Map 2.3 and Map 2.4 . The Water Exploitation Index has been calculated at RBD scale (supplemented with national scale where RBD data were missing) on annual resolution (based on the information of the latest available year), as well as on long-term average for inter-comparison and to obtain the best available coverage (Map 2.3). The same calculations have also been obtained excluding the abstractions for cooling purposes in electricity production (Map 2.4). Cooling water is considered to be released back to the system (with the exception of evaporative towers) and has been thus used as a relevant proxy for return water, in order to compare how the EU picture is modified if this component is considered as a reduction on the pressure (i.e. the abstraction) (Map 2.4). Relevant abstractions per capita, and cooling water as percentage of total abastrcation are overlaid on the maps for better visualisation of the human pressure excerted. Based on the Water Exploitation Index WEI (as presented in Map 2.3) about 65% of the RBDs analysed are exploiting less than 20% of their water resources, 18% (on average) are exploiting 20-40%, while about 17% are exploiting more than 40%. If cooling water is considered as a return and deducted from the volume of total abstraction (Map 2.4) then the above numbers change to 70%, 10% and 12% of the analysed RBDs respectively. It is to be noted that besides the Mediterranean area, stressed RBDs exist also in Central, Northern and Eastern Europe.

[1] The current formulation of the WEI+ as proposed by the EG WSD in the relevant WEI+ Fact Sheet and endorsed by the Water Directors in May 2012 (Faergemann, H. 2012) is: *WEI+ = (Abstractions – Returns) / Renewable Water Resources*.
Abstractions and Returns refer to a lump sum from the different sectors (i.e. public water supply, agriculture, industry etc.), while two options have been proposed for the calculation of Renewable Water Resources (RWR) based on the hydrological balance equation:

(a) RWR = Precipitation – Actual Evapotranspiration + External Inflow – Change in natural storage
(b) RWR = Natural Outflow = Outflow + (Abstraction – Return) – Change in artificial storage

Map 2.3 Water Exploitation Index (WEI %) for European RBDs *(top: the water availability is calculated on an annual scale based on information from the latest available year; bottom: the water availability is calculated as the long-term annual average - ltaa)*



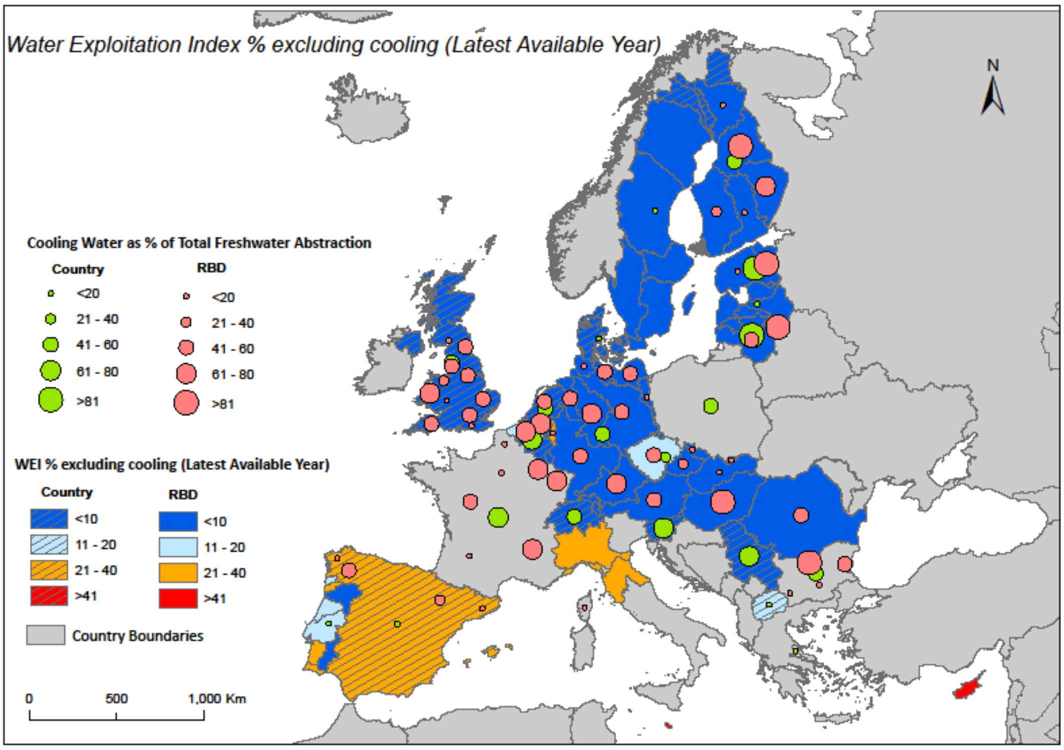


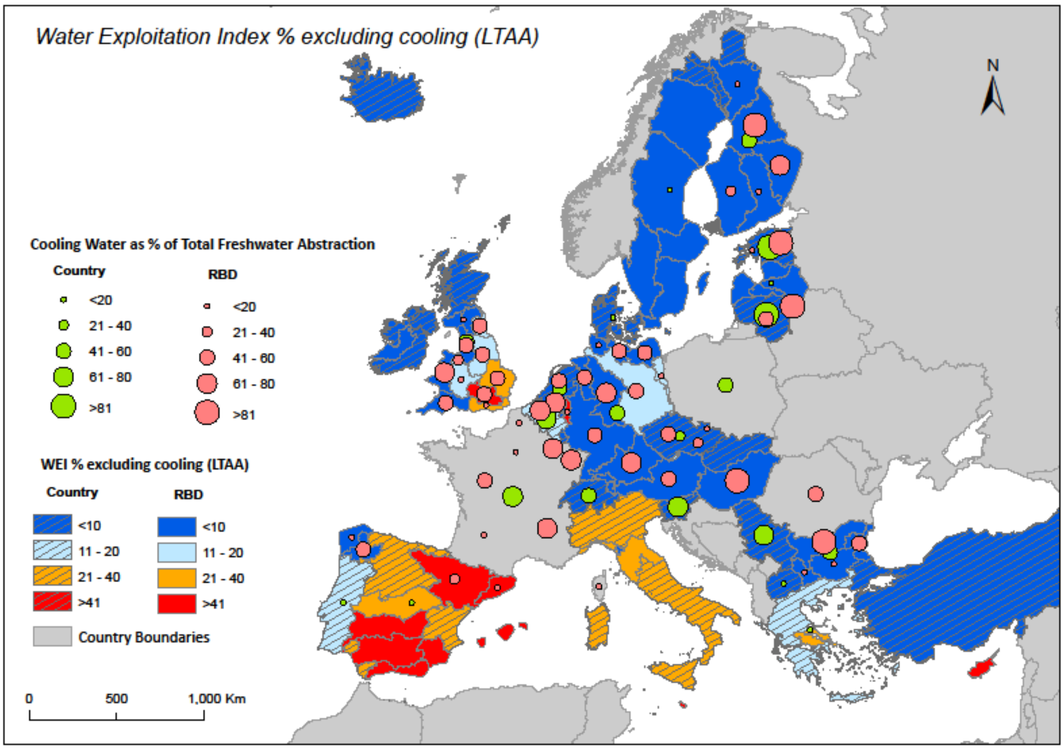
Note: WEI calculations as follows: top map: WEI (%) = [Annual Freshwater Abstraction] / [Annual Water Resources Availability], with reference to data of the latest available year; bottom map: WEI (%) = [Annual Freshwater Abstraction] / [Long-term Annual Avearge Water Resources Availability].

Source: Data come from multiple sources, and refer to a range of years, as presented in Map 2.8 and

Map 2.10 in the following section.

Map 2.4 Water Exploitation Index (WEI %) for European RBDs excluding Cooling Water for electricity production from the abstractions ***(top: the water availability is calculated on an annual scale based on information from the latest available year; bottom: the water availability is calculated as the long-term annual average - ltaa)***





Note: WEI calculations as follows: top map: WEI (%) = [Annual Freshwater Abstraction – Abstraction for Cooling purposes in electricity production] / [Annual Water Resources Availability], with reference to data of the latest available year; bottom map: WEI (%) = [Annual Freshwater Abstraction – Abstraction for Cooling purposes in electricity production] / [Long-term Annual Avearge Water Resources Availability].

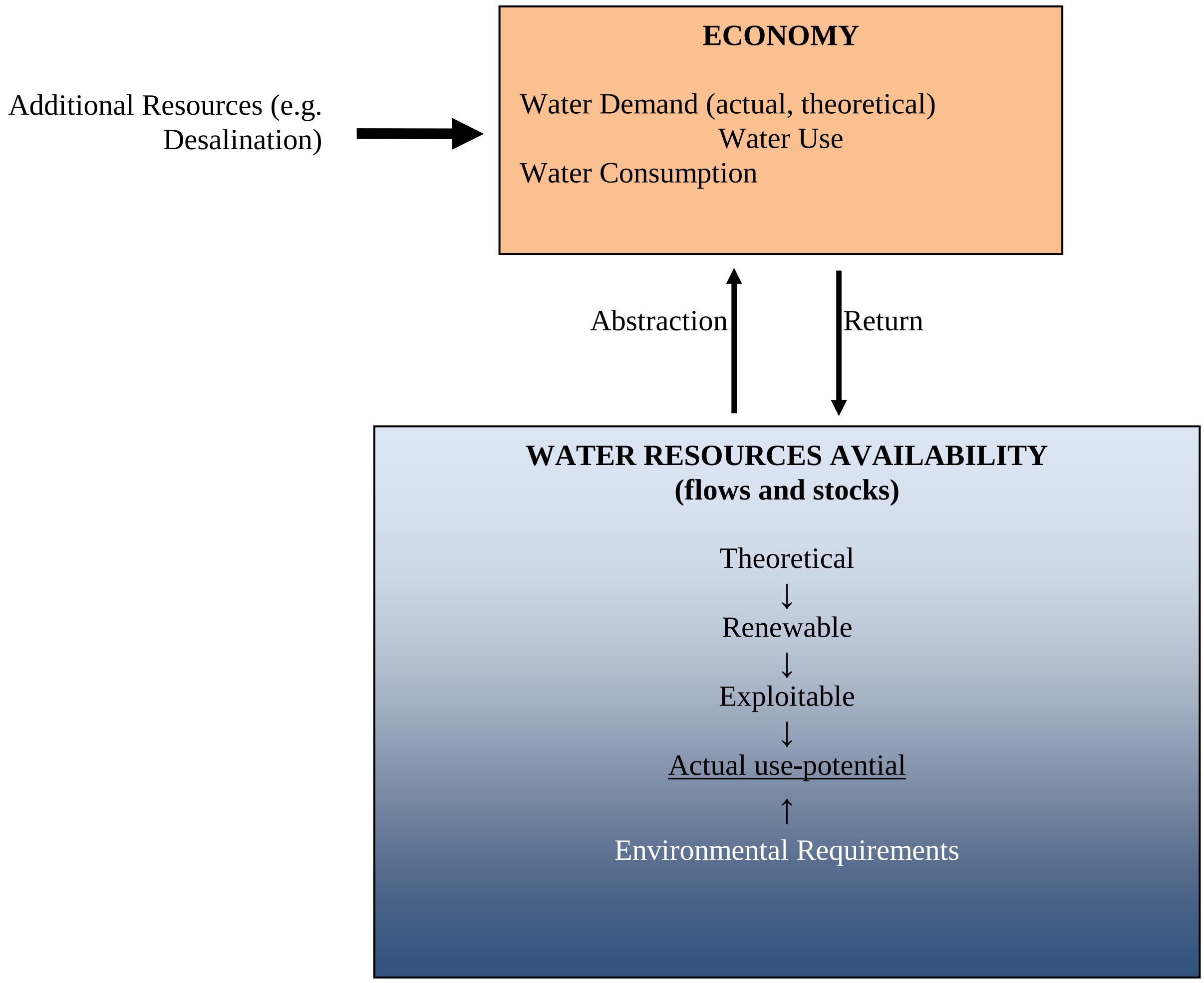
Source: Data come from multiple sources, and refer to a range of years, as presented in Map 2.8 and Map 2.10 in the following section.

Methodological issues and relevant parameters

Identifying and characterizing water stress conditions is a complex task due to the fact that water scarcity is at the interplay of natural and socio-economic phenomena, is subject to the spatiotemporal scale of analysis, while its severity clearly relates to the regional impacts and the effects on ecosystems. Indicators such as the Water Exploitation Index and the updated WEI+ can underpin the assessment of water scarcity, they are subject to limitations and constraints mostly due to their relatively simplified view of the water balance, and should thus be carefully interpreted and supplemented with additional parameters to jointly convey robust conclusions.

By definition, water scarcity or stress occurs when “availability” at a certain time step is not enough to meet the “demand”. If this is a short term condition, we refer to water stress, but if the problem develops further in time (longer term condition) or if it re-occurs often for a certain time period (e.g. every summer) we then refer to water scarcity. There are numerous relevant parameters which fall under the “availability” or the “demand” part of the equation, bearing different physical meaning and resulting thus different interpretations (Figure 2.4).

Figure 2.4 The flows of water between environment and economy, and the relevant parameters related to water scarcity



Source: Compiled by the authors, drawing on discussions within the Expert Group on Water Scarcity and Drought (EG WSD)

Water resources availability as a term is used in very different ways, addressing separate or combined water volumes that are part of the water system. Notions such as ‘natural resources’, ‘renewable water resources’, ‘exploitable water resources’ are often confused. In most cases, water resources are restricted to the actual available for use volume since part of the resource may be practically unrecoverable due to specific geological and morphological conditions (i.e. deep aquifers, direct discharges to the sea in coastal aquifers, etc.) (example provided in Box 2.1). While this is very difficult to estimate, environmental and other legal water requirements (i.e. as defined by transnational treaties) need to be considered as well since they in fact limit the available water that can be finally exploited and used for consumptive purposes. Evidence exists that the 25-50% of the mean annual river flow in different basins needs to be allocated to freshwater-dependent ecosystems to maintain them in good ecological status (Sánchez Navarro and Schmidt, 2012). Excluding this volume from the available for exploitation water may result in changing the severity level of water scarcity conditions. Environmental Water Requirements (EWR) for different European basins or drainage regions are also presented in Smakhtin et al., 2004, as the percentage of the available water required to be maintained for environmental purposes. These percentages vary (e.g. 40% for the Danube, 34% for the Dnieper, 45% for the Elbe, 47% for the Oder, 44% for the Rhine, 40% for the Rhone and 35% for the Seine) but generally they lie in the range of 40%. Returned water (into the same hydrological unit where abstraction occurs) can also affect the water stress level of an area. Depending of course on the water quality and location where the return occurs (e.g. upstream enough to be exploitable by other users downstream) this volume may be an important addition to the system alleviating potential problems, and thus needs to be taken into account when calculating the overall balance (availability-demand) of a region to define the relevant water scarcity).

Box 2.1 Estimation of the Actual Available Water Resources and WEI+ in the Malta River Basin District

(Drafted by Manuel Sapiano, Malta Water Resources Authority, Regulation Unit)

In small islands and coastal river basins, natural subsurface discharges of groundwater at the coast can reach levels of around 50-60% of the mean annual recharge to groundwater and is thus an important factor in the water balance calculations. It is one of the main factors limiting groundwater availability and its non-consideration has the effect of artificially increasing the 'Available Renewable Water Resources' since freshwater lost by this natural process is not available for abstraction and subsequent use.

Additionally, one should note that the small distance to the coast and other topographical considerations limit the proportion of rainwater runoff which can be collected/harvested for eventual re-use. Due to their small size, the proportion of rainwater runoff generated in near coastal areas (and thus not recoverable) assumes higher significance compared to bigger continental river basins. Similarly to subsurface discharge, not taking this fact into consideration results in artificially increasing the 'Renewable Water Resources'

The main impact of these two factors, namely increasing the 'Renewable Water Resources' can result in artificially low indices of Water Exploitation for these river basins if not properly accounted for, which do not reflect the reality which these basins are facing.

Considering data from Malta RBD as a case study, deducting the natural subsurface discharge and unrecoverable surface runoff from the ‘Renewable Water Resources’ (as these volumes cannot actually be recovered) results in a better estimation of the actual full use-potential. The resulting WEI+ is 69% for the long-term average and 99% for the year 2010, demonstrating conditions of heavy exploitation, as presented in the Table 2.2 below. If these volumes had been considered as available for abstraction, the WEI+ value would have been 40% and 55% respectively, illustrating a lower and unrealistic exploitation of the RBD.

Table 2.2 Calculation of the Water Exploitation WEI+ for Malta RBD, taking into account the volume of water resources that cannot actually be recovered.

Parameter	LTAA	2010	Comments
Precipitation (hm3)	174	162	
Actual Evapotranspiration (hm3)	105	97	assumed at 60% of total precipitation in both cases
Renewable Water Resources (hm3)	69	65	
Natural subsurface discharge (hm3)	23	23	
Unrecoverable surface runoff (hm3)	6	6	Estimated at 25% of total surface runoff generated (initial estimate)
Actual available Water Resources (hm3)	**40**	**36**	
Total Abstraction (hm3)	37,5	43,7	
Returned water (hm3)	10	8	return from leakages - value is reducing due to leakage programme
WEI+	**69%**	**99%**	

Source: Data provided by the EIONET NFP of Malta (Malta Resources Authority, Regulation Unit) during the EEA Consultation of the WEI+ in August 2012

It was recognized during the discussions of the CIS EG WSD that MSs, when calculating water scarcity and stress indicators, often use different parameters from the "pool" of the ones relevant to the "demand" component of the water balance, which is partly driven by their data availability. Using water abstraction vs. water use vs. water demand are all relevant under the general context of stress and risk, but it is very important to clarify the parameters used and make it transparent since the resulting indicators convey different messages (Box 2.2).

Using "abstraction", we can evaluate how much pressure we are putting into the natural system, how much we are stressing a given system based on the degree of exploitation which is aligned with the WFD objectives (intensity of use of available natural resources). If we choose the "water use", then we calculate more of a consumption index, especially in the case that the returns are also considered. If we choose the "water demand", we then depict water scarcity and we can compare it to either the natural availability or to the availability after additional supplies have been included (i.e. desalination) and this would be more useful from a management perspective. Yet, in this case, it is important to know if the "water demand" refers to the actual or to a theoretical value, as the latter can bias the results. Furthermore, by calculating different ratios of these parameters (e.g water demand/water abstraction, water use/water demand, water use/water abstraction, etc.) one can obtain additional useful indicators on sufficiency of the supply, dependency from additional resources, water efficiency and losses, and have a complimentary picture of the water scarcity situation. Thus, in cases that water abstraction is currently not a pressure, yet demand is high and met by other means (e.g. from water transfer, desalination, etc.) we could have an indication of water scarcity conditions, current or potential future ones. A relevant example is the case of Athens, where water is not abstracted in-situ, but transferred from an ex-situ abstraction location 300 km away. The water exploitation index (abstraction/availability) for Athens would show as non-stressed, yet scarcity conditions are acute due to high demand. In Germany, water use can be higher than abstraction in various cases, as well as in the Segura RB in Spain, where portion of the demand is met by desalination. In SK there are permits for abstraction and return, so the actual consumed water (for which the user pays) is the difference between the abstraction and the return. What is important to stress is that the availability of these data, i.e. water abstraction, use, demand, vary from MS to MS, as well as their methods of calculating them (in case they are not actual measured data). For example, in some countries it is difficult to get real abstraction data, in others it is difficult to calculate the exact volume abstracted from illegal wells, while agricultural demand is often calculated on a theoretical basis.

Box 2.2 A conceptual analysis of "Water Quantity Stress"

(Drafted by Rudy Vannevel, Flemish Environment Agency (VMM), Analysis & comments on the Water Exploitation Index WEI+)

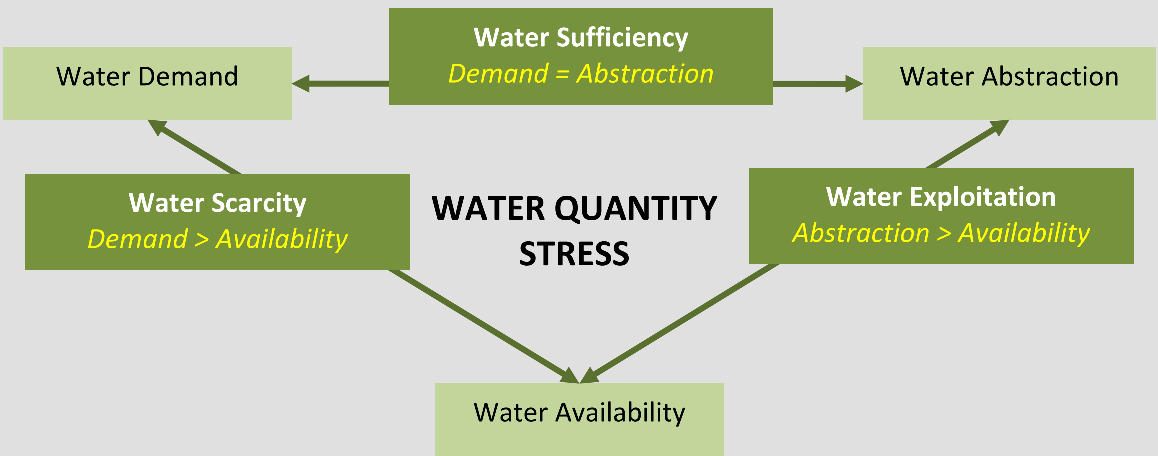
Water stress is a broad term, indicative of the pressure on the quantity and quality of water resources. Water stress relates to water management by controlling supply, improving water use efficiency, avoiding groundwater over-exploitation, restricting water use, reducing losses, improving water recycling, etc. (EEA and UNEP, 1997: 4-7). According to the EEA and UNEP (EEA and UNEP, 1997: 5-6), water stress is determined by the available resources, abstraction, demand, supply and use.

Water Quantity Stress (WQntS) is presented as a conflict model of human water dependency between the factors sectoral water demand, water availability and water abstraction (Figure 2.5). The indicators related to WQntS are based on the absolute values of these factors, and represent water scarcity, water exploitation and water sufficiency. WQntS indicator values are not quantitative, but metrics could be developed in this way. The values must provide information on the extent to which the policy objectives are met.

- *Water scarcity* is indicative of the human needs of water volumes. The balance between availability and demand must guarantee sustainable development (policy objective).
- *Water exploitation* is an indicator of the intensity of use of available natural resources (policy objective). It contributes to avoiding overexploitation and the sustainable use of renewable resources.
- *Water sufficiency* indicates if the abstraction (and consequently also supply and use) meets the demand, avoiding shortages and spills (policy objective).

Optimal use and environmental conditions result in a WQntS reduced to "zero" and represented by a balanced and sustainable water mass flow. Any deviation from the optimal 'balanced' situation is a stressed situation.

Figure 2.5 Schematic representation of "Water Quantity Stress" factors and indicators



Source: Vannevel, Rudy, 2012.

Scales

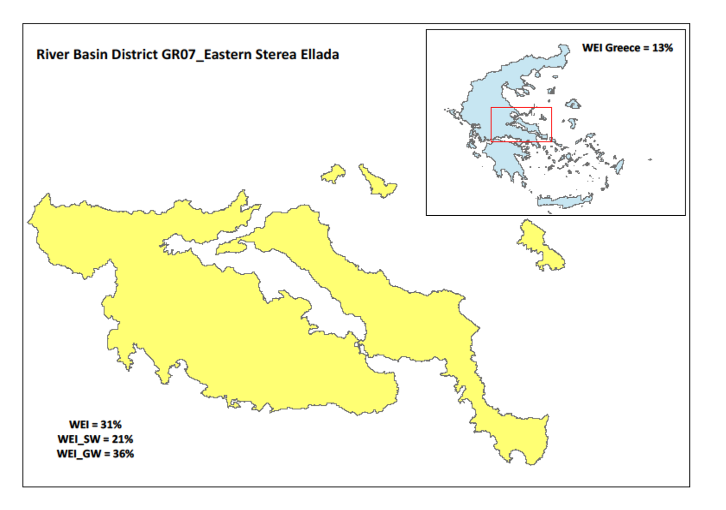
When assessing water scarcity conditions, the selection of relavant spatial and temporal scales is essential to the analysis. The traditional **spatial scale** of implementation of the WEI at country level is too aggregated and fails to depict the regional variability within the country. Thus, a country may be depicted as not stressed, yet there might be areas or River Basin Districts (RBDs) which face water stress conditions and this is leveraged out at country level. Furthemore, even within an RBD, basins may exist which face stress as compared to others that are non-stessed. Concluding, the national level is seen as neither accurate nor precise in order to assess the prevailing water stress. To correctly represent water scarcity problems and meet awareness purposes, hydrological entities (where the hydrological cycle and water balance closes) are much more suitable than the administrative units. Finally, it is important to emphasize that summing up the surface and groundwater resources and abstractions also empedes a correct identification of the pressure. The WFD considers surface and groundwater bodies separately. Some MSs (e.g HU) calculate in practice the WEI+ separately for surface and groundwater bodies. The importance of scaling and further decoupling surface water exploitation from groundwater exploitation is showed in the example for Greece in Box 3.3.

Box 2.3 The importance of scaling and decoupling in the estimation of water exploitation and water stress

The spatial scale of analysis is essential in the accurate representation of water scarcity conditions. Highly aggregated scales like country level fail to depict the full problem as deficits between water resources availability and demand in one area can be leveraged by surpluses in other areas. Similarly, separating between surface and groundwater resources can further support the assessment of water exploitation. Cases where one of the resources (e.g. groundwater) is overexploited may not appear when availability and abstractions from all sources are calculated as sums, and the appropriate measures to counter the water stress may be missing.

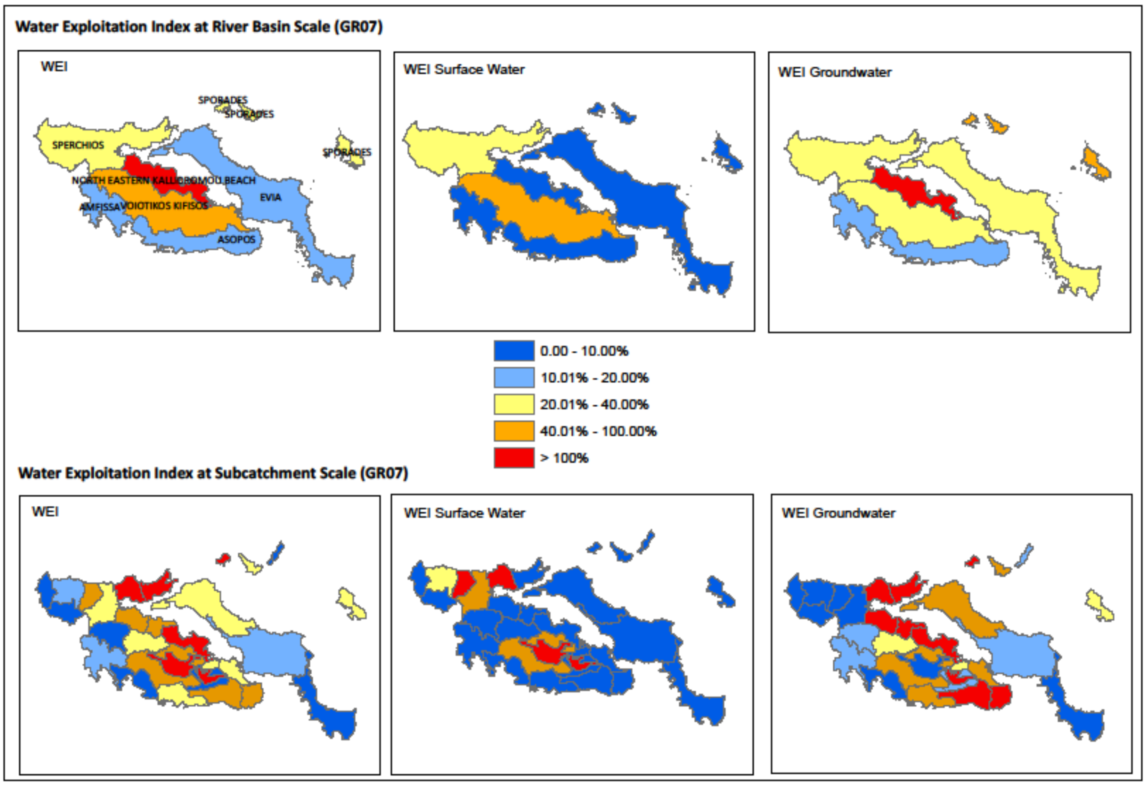
The Greek case of the RBD of Eastern Sterea Ellada (GR07) is a nice illustrative example. The Water Exploitation Index (WEI) calculated based on the long term average availability places Greece as a non-stressed country with a WEI of 13%. Yet, the RBD of Eastern Sterea Ellada has a much higher WEI of 31%, with its groundwater being overall more exploited than surface water (Map 2.5). A further analysis conducted at River Basin scale and sub-catchment scale, decoupling also surface water (WEI_SW) and groundwater (WEI_GW) exploitation (Map 2.6) shows great variability within the RBD, with some basins and catchments being overexploited while others are not-stressed and reveals a large range of exploitation rates of the surface and groundwater. This scale of analysis can better support the identification of the problem (together with additional management indicators) and guide targeted actions.

Map 2.5 The WEI for the Greek River Basin District Eastern Sterea Ellada (GR07)



Note: WEI is 31%, and if calculated separately for surface (21%) and groundwater resources it is estimated at 21% and 36% respectively.
Source: Compiled by the ETC/ICM based on data provided in the Drought and Water Scarcity Management Plan of GR07 which has been developed by the Special Secretariat for Water of the Hellenic Ministry of the Environment, as part of the draft WFD River Basin Management Plan (the RBMP is under consultation – it has not been finalized yet) (Hellenic Ministry of the Environment, Energy and Climate Change and NAMA S.A 2012).

Map 2.6 The WEI at river basin and sub-catchment scale within the Greek RBD Eastern Sterea Ellada (GR07)

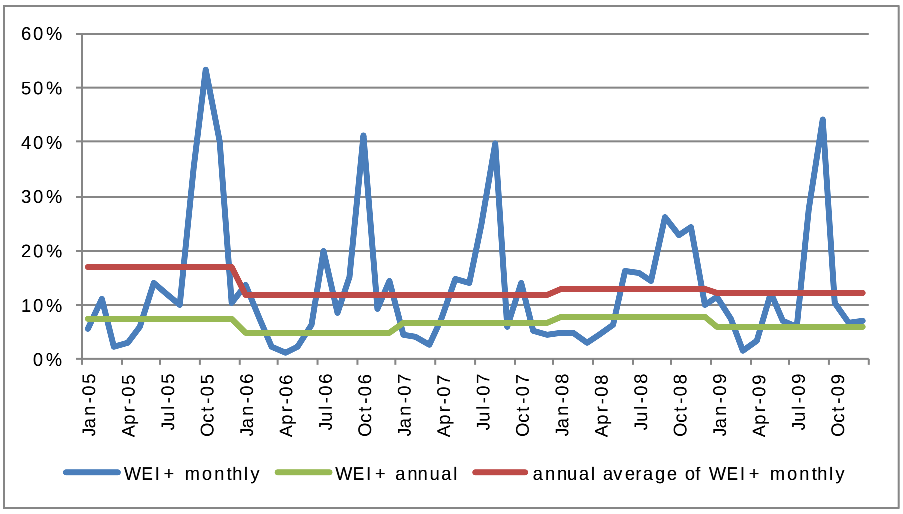


Note: WEI total (left), for surface (middle) and groundwater resources (right) at river basin (top) and sub-catchment scale (bottom) within the Greek RBD Eastern Sterea Ellada (GR07).

Source: Compiled by the ETC/ICM based on data provided in the Drought and Water Scarcity Management Plan of GR07 which has been developed by the Special Secretariat for Water of the Hellenic Ministry of the Environment, as part of the draft WFD River Basin Management Plan (the RBMP is under consultation – it has not been finalized yet) (Hellenic Ministry of the Environment, Energy and Climate Change and NAMA S.A 2012).

Similarly, the **temporal scale** of implementation can hinter the identification of water stress conditions which may be evident during some years, or reccurent over some months (e.g. summer period). Considering long-term average availability can communicate misleading messages, leveraging dry years and confusing the assessment. Additionally, due to climate change one cannot consider that precipitation conditions of e.g. 1980-2000 are representative in 2012. Furthermore, even an annual scale application could hide the seasonal imbalances and the stress experienced over some critical months (e.g. summer, example of the Czech Republic-Morava RB in Figure 2.6, Hungary and the Slovak Republic in Figure 2.7). On the other hand, flagging areas as water scarce on the basis of few episodes and sporadic events is also biased. Thus, the selection of appropriate temporal scale is crucial in the analysis and subject to the prevailing conditions in the area of interest.

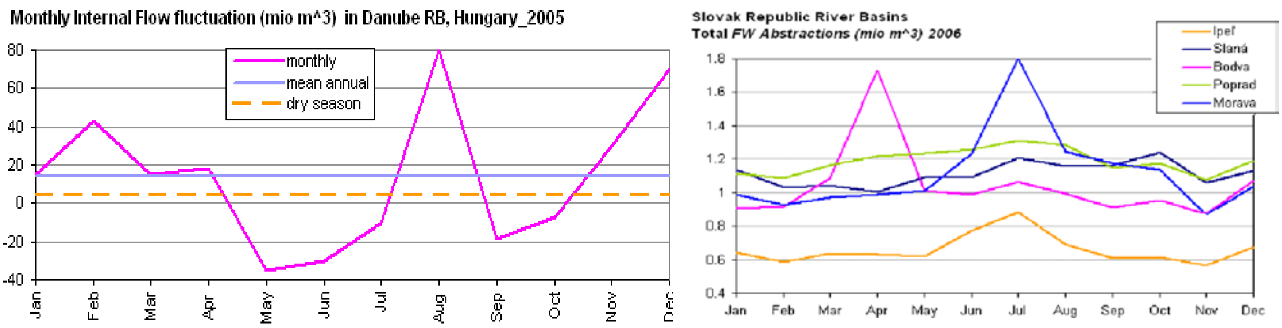
Figure 2.6 Variability of the Water Exploitation Index (WEI+) in the Morava RB, in the Czech Republic for the period 2005-2009 over a monthly scale.



Notes: WEI+ has been corrected to further include water requirements (environmental and other) and returned water. The analytical expression is WEI+ = Abstraction / (Water Availability – Water Requirements + Returned water)

Source: EG WSD, provided by the representative of CZ

Figure 2.7 Seasonal variability of water availability and abstractions in Hungary and the Slovak Republic



Monthly variability of water availability in the Danube River Basin, Hungary for the year 2005 (Dry season: April-September)

Monthly variability of total freshwater abstraction in Slovakian River Basins for the year 2006

Source: Compiled by the authors based on WISE-SoE data reported in the Test Data Exchange 2008, EEA

Thresholds

Water scarcity characterization is only relevant against defined threshold values and classes, i.e. levels beyond which the system can be judged as unsustainable. In general, an environmental threshold is described as a point of a natural system at which the essential characteristics of its present state change dramatically, or where this impacts socio-economic systems (Parry et al., 1996; Sprinz and Churkina, 1999). In the context of water scarcity, thresholds are the relevant trigger points that offset adverse effects on the environment (i.e. failing to meet environmental requirements) or the society. Defining proper thresholds is a very challenging task since they need to be robust enough, yet sensitive and able to reflect a correct representation. Thresholds could be defined on the basis of impacts, vulnerability, or in relation to environmental needs of the ecosystem (Box 2.4) and the good ecological status of the water bodies. To this extend it could make sense to have a common indicator, but define thresholds based on regional conditions, or implementing an intercalibration exercise. A broad categorization of thresholds is presented in Table 2.3, where proposals and preliminary ideas for defining thresholds (explored also within the EG WSD) have been incorporated. Some of the approaches could fail to provide evidence of real risk if not properly intercalibrated and validated against real conditions (e.g. absolute values) they can nevertheless simplify the assesments and awareness purposes. Others (e.g. specific thresholds) adopt a more risk-oriented approach and are tailored to impacts, and if based on robust common criteria can reflect better the local particularities.

Table 2.3 Categorisation and methodological approaches in defining thresholds for the Water Exploitation Index

Type of thresholds	**Methodological approcah**	**Ideas / suggestions**
Empirical Thresholds	Based on absolute values	- Fixed percentages, but adjusted in comparison to the 20%, 40% of the original WEI to reflect the inclusion of the new parameters (e.g. returned water) - Adopt a sensitivity approach showing how WEI+ changes if we preserve different percentages (e.g. 20%, 30%, etc.) for environmental purposes
Generic Thresholds	Based on statistical values (e.g. percentiles) and timeseries analysis (frequency and return intervals)	- Correlation with other indicators e.g. the Standard Precipitation Index (SPI), the Standrad Runoff Index (SRI), the Water Deficit (in mm or m^3/capita). Relation of thresholds to a probability density function of these indicators. - Creation of timeserie of deficit, annual and/or monthly, and counting of the number of events with deficit within the given period. Implementation of statistical analysis to define probabilities of occurrence of events of different magnitude and duration, and definintion thresholds based on this.
Specific Thresholds	Linked to local conditions and constraints for specific uses	- Relate the thresholds to existing storage accumulated over a previous period (x months). The degree of vulnerability or scarcity increases as past accumulated storage fails to cover the current deficit. Based on the return period of these critical situations, thresholds can be defined for different probabilities of occurrence. - Correlation of low flows with WEI+, and statistical evaluation - Correlation with environmental requirements and/or good ecological status of water bodies. Not meeting environmental requirements is the tipping-point for setting thresholds. These can differ among the different areas in absolute value but the underlyining methodology for deriving them should be the same.

Box 2.4 Use of environmental flows as thresholds for the WEI+ in UK

(Drafted by Nicola Poole, Environment Agency, UK)

Estimating where water demands are a high proportion of the natural renewable resource using the WEI+ calculation provides an indication of levels of water exploitation. But what this doesn't show is whether the water environment is likely to cope with that level of exploitation. It is therefore important to compare water exploitation against thresholds representing environmental needs.

The UK provides a recent example of using thresholds based on environmental requirements in order to determine if water exploitation could result in water stress (Environment Agency, 2012). In order to define the boundaries between stress classes, thresholds were chosen based on Environmental Flow Indicators (EFIs). The EFI is a percentage deviation from the natural river flow represented using a flow duration curve. This percentage deviation changes with different flows, and also changes depending on an assessment of the ecological sensitivity of the river to changes in flow. The EFI is set at a level which is thought to support Good Ecological Status.

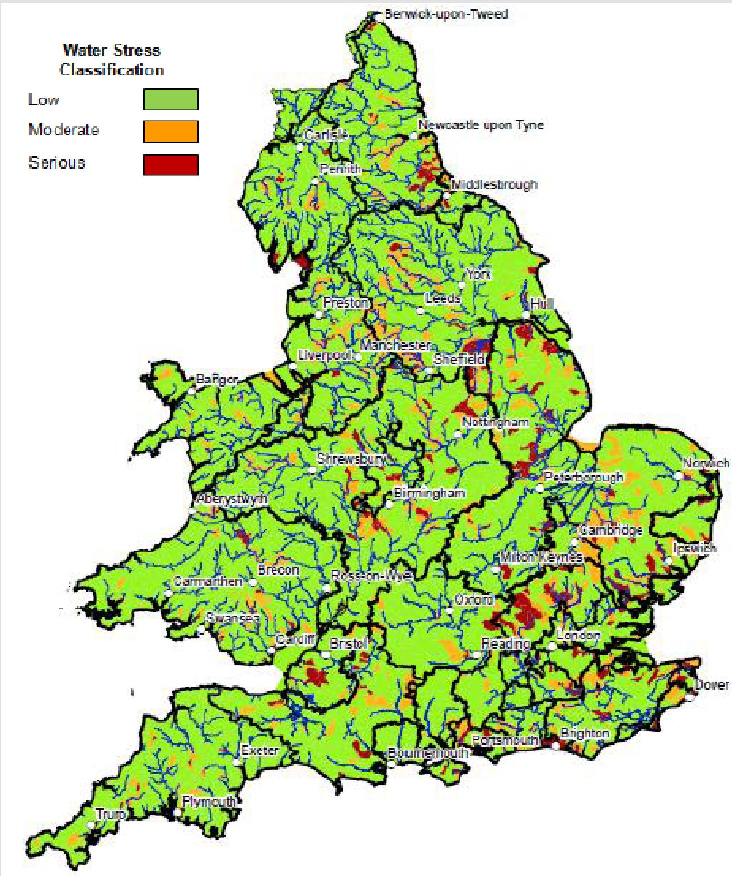
In the current UK approach, firstly, exploitation was determined using the WEI+ calculation. Secondly, the WEI+ result was compared against the EFI thresholds. If the water exploitation is below the EFI threshold then that water body is classed as low stress because the level of abstraction pressure or exploitation is deemed acceptable and from a flow perspective a good ecological status is likely to be supported. If the level of exploitation is above this threshold, there is a risk of ecological damage and the level of water stress is classified as moderate or serious, according to the criteria set out in Table 2.4. The water body stress classification for the current situation is shown in Map 2.7.

Table 2.4 Criteria for classifying levels of water stress

Classification	Criteria
Low	Water exploitation is below the Environmental Flow Indicator thresholds
Moderate	Water exploitation is <25% above the threshold for low water stress
Serious	Water exploitation is >25% above the threshold for low water stress

Source: Environment Agency, 2012

Map 2.7 Water body stress classification at the current situation



Source: Environment Agency, 2012

To further strengthen the analysis, the assessment of water body exploitation and stress was also repeated for four future scenarios. Whilst some water bodies may only be classed as low or moderate stress now, the impacts of changing demands and population growth, or a changing climate, could tip the balance in the future. Thus, it is also important to look at the areas that might become stressed in the future. The scenarios implemeneted, and the data sets behind them, were drawn from a previous Environment Agency study published in December 2011 to support the case for change in Defra's White Paper – Water for Life (Defra, 2011). They reflect the worst and best-case pressures on water resources from severe to moderate impacts of a changing climate and high and low water consumption, cross-combining these situations. The biggest 'impacts' of the scenarios are in the water bodies that are already classed as serious. The main changes are increases in the number of moderate and serious water stress catchments within: East Anglia (particularly North West Norfolk and areas around the Broads; The Medway, plus areas of Chalk geology in North Kent and along the South Coast; The lower reaches of the River Trent catchment, between Nottingham and Sheffield; The River Severn catchment to the West of Birmingham.

This approach is based on a nationally-consistent appraisal of the level of exploitation of water resources. But local environmental protection needs (such as specific protection to be afforded to Habitats Directive sites) may require additional assessment.

Data availability and limitations

Regarding the data available to calculate the WEI across the EU, different datasets exist, either as products of reporting (e.g. WISE-SoE#3 on Water Quantity, EUROSTAT Joint Questionnaire on Inland Waters and Regional Environmnetal Questionnaire, WFD RBMPs, FAOSTAT, AQUASTAT) or modelling (e.g. WaterGap, LISFLOOD) or a combination of both (**EEA Water Accounts under the ECRINS reference system**), and are publicly available. This empowers different actors to run various calculations to represent water stress and scarcity, considering each time different assumptions, formulas, data sources (where the definitions of parameters are not necessarily matching) and various constraints. Accordingly, the results can be interpreted differently while the quality of the results has to be carefully considered with regards to the origin and purpose.

The analysis of the WEI+ and the current ongoing effort towards its calculation across the EU at the appropriate disaggregated spatial and temporal resolution (undertaken within the ETC/ICM and with consultation with the MSs), suggests that **data to underpin a solid assessment of water scarcity conditions are still imperfect**. The MSs' effort to support these assessments has been significant and many countries have reacted to the EEA call for enhancing the EU water quantity dataflow, but this effort needs to continue and intensify. For the second round of RBMPs, improved water scarcity assessments are also needed on a European level to reflect in water scarcity situations as seen in a river basin. On the regional level, developing adequate management strategies requires for a more thorough analysis of the occurrence and causes of water scarcity as a phenomenon that is distinct from droughts. The first round of RBMP reporting showed a deficit in precisely this area (Schmidt and Benítez, 2012), while improving knowledge and governance was the most mentioned group of measures in the RBMPs (mentioned in 85% of RBMPs, Schmidt and Benítez 2012).

It is thus being identified that cautious interpretation should always be applied to avoid biased conclusions, and that additional tools are needed in order to improve and fortify our ability to characterise and manage water scarcity: blended indicators as satellites to the WEI+, detailed regional water balances (as the core of the analysis) based on harmonised standards, adequate knowledge of ecological flows, regional drought risk maps, etc. **The current effort of the EEA Water Asset Accounts has focused on building detailed water balances at a very disaggregated catchment and monltly scale based on MSs' data, and suggests that this platform can form a solid basis for**

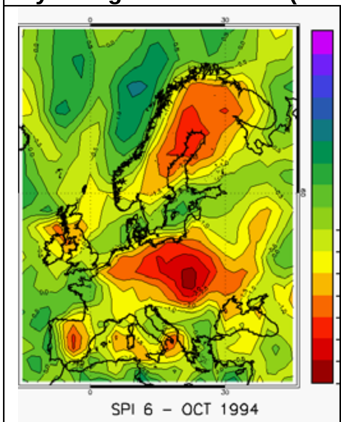
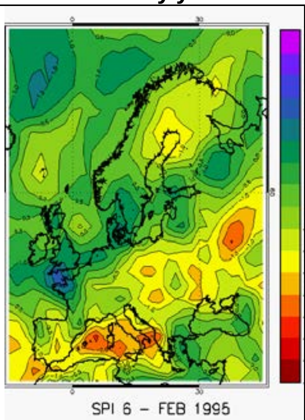
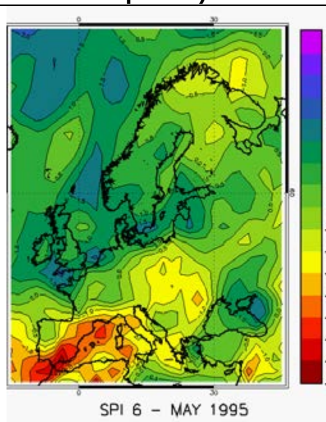
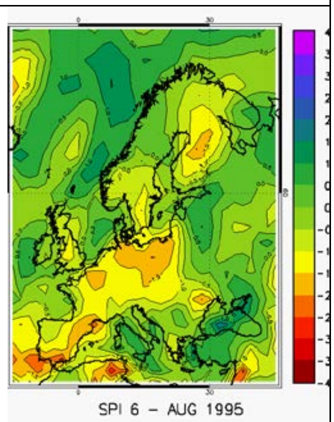
the regular calculation and update of any agreed with the MSs' indicators of water scarcity and for intercomparison among EU areas.

2.2 Main drivers and pressures

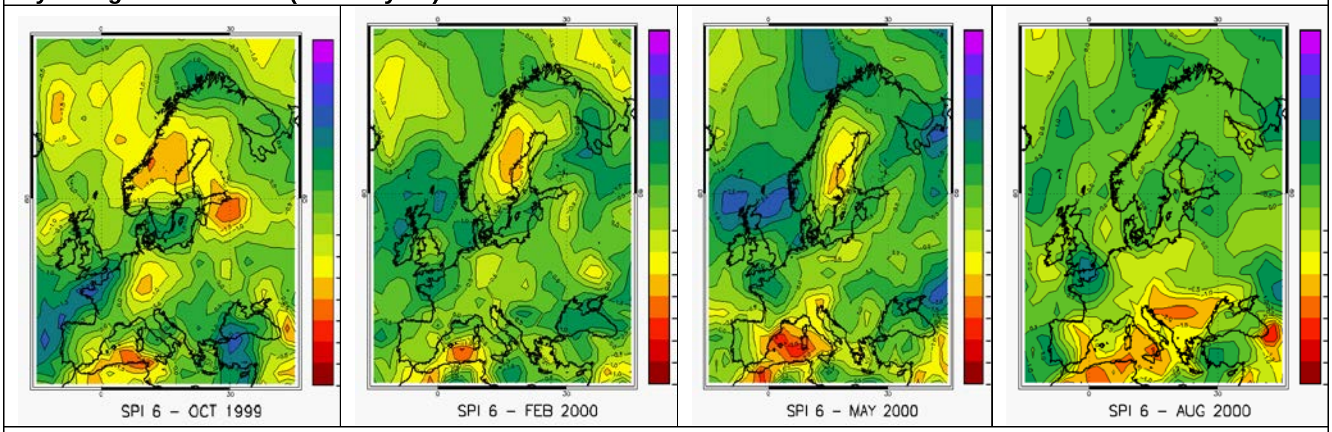
The driving forces of Water Scarcity are, as stated in the 2nd Interim Report (EC, 2007b) on water scarcity and droughts, "imbalance(s) between water supply and water demand". Therefore increasing problems of water scarcity can result either from the increase of abstracted volumes or the decrease of natural water resources availability. Many interrelating factors are responsible for these imbalances and can be divided in the following gross categories: population growth, human activities (including land use change), environmental pressures and climate change.

Climatic changes may cause anomalies in precipitation and evapotranspiration leading to deficit of the available water resources. Based on a review conducted by the Académie des Sciences, De Marsily (2006) pointed out that "the effects of climate changes for the next century are fairly well predicted as far as the temperature is concerned, but that their hydrologic effects are really much more uncertain". In a report drafted for the purposes of the Portuguese Presidency, De Marsily (2007) concluded, that the consequence, of climate change in terms of water scarcity in the EU, under normal conditions, is expected to be a strong decrease of water resources in Southern Europe, affecting mostly agricultural production. The evolution of the precipitation in Europe can be illustrated using different meteorological indicators such as the Standard Precipitation Index (SPI). The evolution of the 6-month SPI for the EU from 1990-2011 is presented in Figure 2.8 below. The milestone years 1995 (one of the most dry year in the 90s), 2000 (normal year), 2003 (the driest year in the 2000s) and 2012 (current year) have been used to allow comparison of precipitation trends. It is interesting to observe that 2003 (one of the driest years in the 2000s) when compared with 1995 (one of the driest year in the 90s) demonstrates much higher SPI values covering more EU areas and for all seasons, which means that this episode was more severe both in terms of magnitude and duration, as well as extent. Trends of reduced precipitation can be observed at regional scale, for example in Cyprus according to a long series of observations, the mean annual precipitation, including snowfall was estimated at 503 mm, and from 2000 until now has been reduced to 463 mm (Water Development Department, Republic of Cyprus).

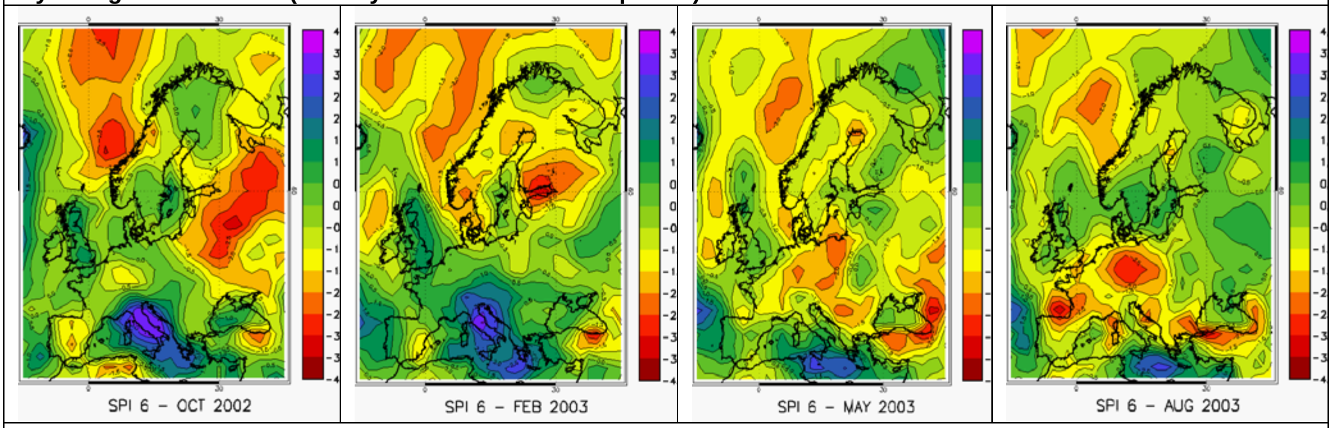
Figure 2.8 Evolution of Drought in Europe based on the 6 months Standarized Precipitation Index (SPI-6)

Autumn	Winter	Spring	Summer
Hydrological Year 1995 (one of the most dry years in the 1990-1999 period)			
			

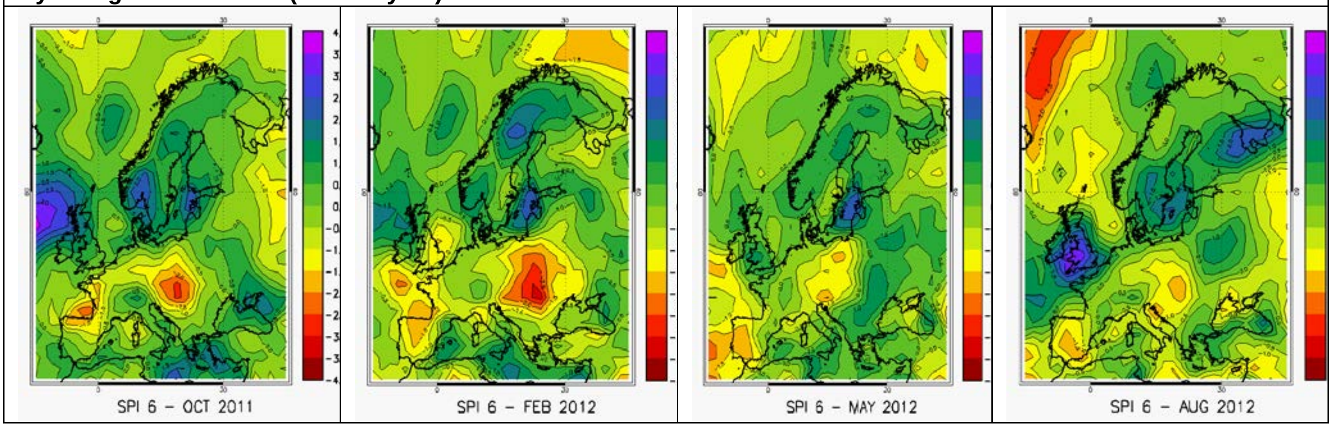
Hydrological Year 2000 (normal year)



Hydrological Year 2003 (driest year of the 2000-2010 period)



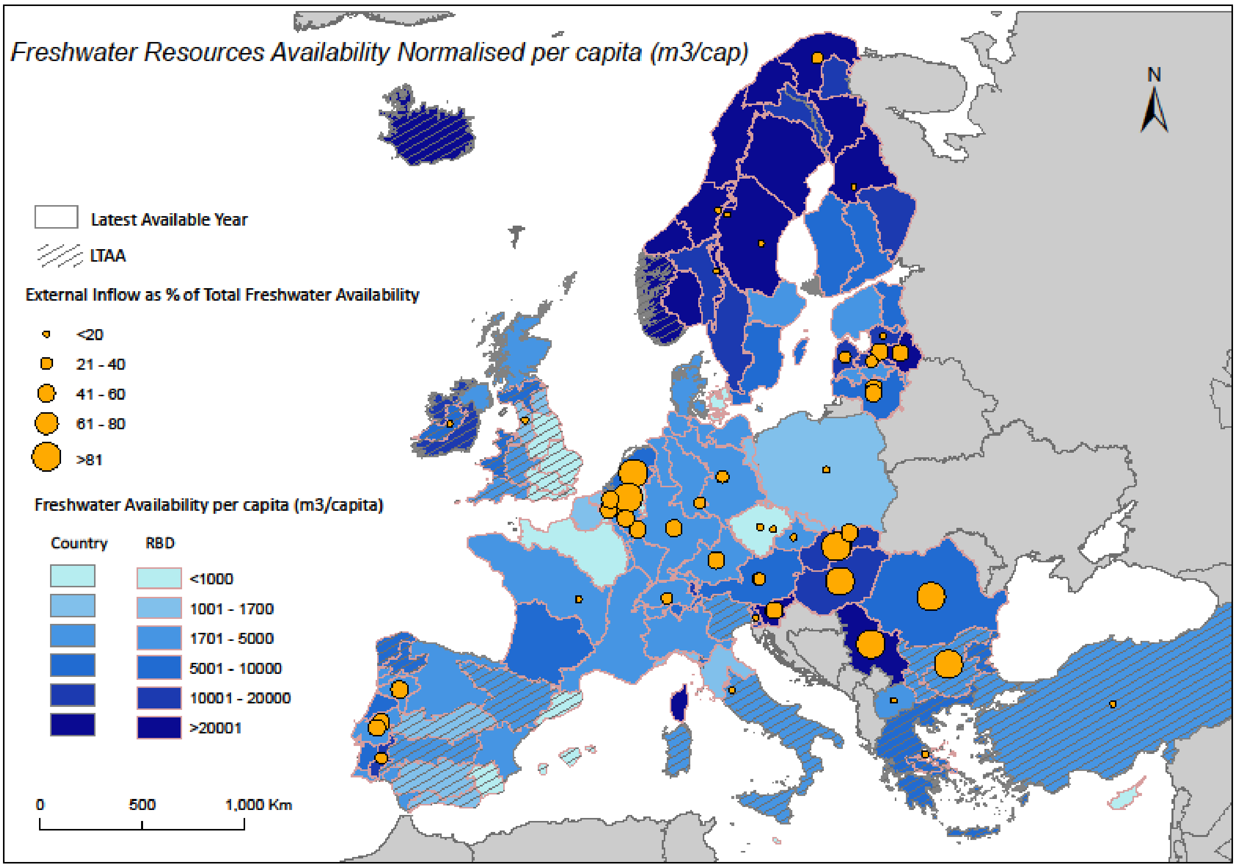
Hydrological Year 2012 (current year)

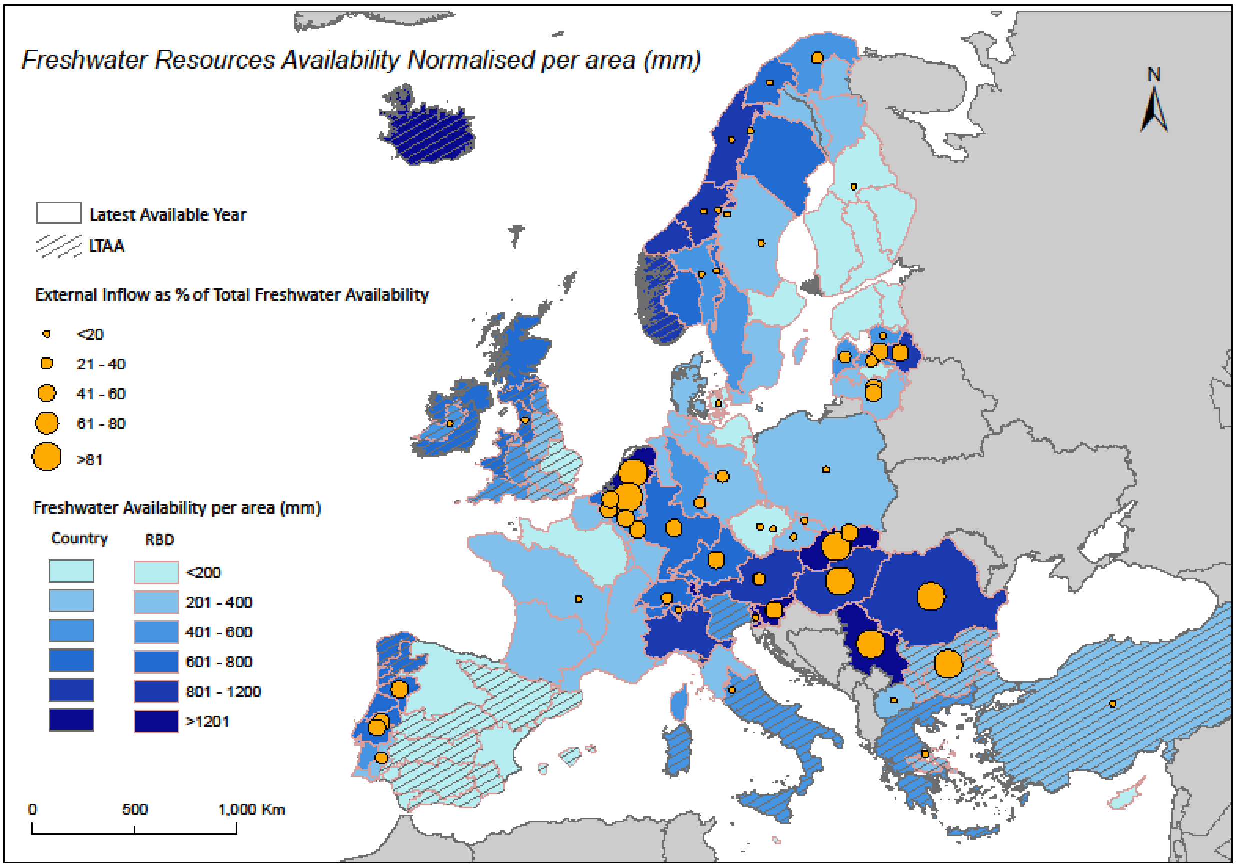


Note: Hydrological year refers to October 1st – September 30th of each year
Source: ISPRA Drought Bulletin, accessed 2012 (http://www.isprambiente.it/pre_meteo/siccitas/index_en.html).

For the water resources, less precipitation and increased drought events translate directly to a pressure on water availability induced by climate. Data collected through the EEA WISE-SoE#3 reporting on Water Quantity and the Eurostat Joint Questionnaire on Inland Waters (JQ IWA), supplemented with other sources (CIS Expert Group on WS&D, official national web sources) have been used to map the freshwater resources availability of Europe (Map 2.8). To provide some metrices of classification and convey comparable mapping, freshwater availability has been normalized both per capita (m^3/cap) and per area (mm) of the RBD. It can be observed that there are regions with relatively low availability per area (e.g. Finland) but when normalized per capita they have clearly high water availability. The Map 2.8 also demonstrates the External Inflow as a percentage of the total availability depicting the degree of dependency from the neighboring territories. It should be stated here (as also mentioned previously in the relevant section on the WEI) that these types of representation of the water availability can serve the purposes of European overview and awareness, but it is clearly understood that the actual "exploitable" water resources (i.e. the percentage of the available water that is in reality possible to capture for use) can be much less due to physical or technical constraints (e.g. ground water lost in karstic aquifers, deep percolation, direct discharges to the sea in islands and coastal areas, etc.).

Map 2.8 Freshwater Resources Availability for Europe *(top: the water availability is normalised per capita (m^3/cap); bottom: the water availability is normalised per area (mm))*





Note: Annual Freshwater Resources Availability has been calculated as Precipitation – Actual Evapotranspiration + External Inflow. Country feedback on this calculation has been incorporated. In the case of LTAA Freshwater Resources Availability this number has been directly provided by the countries.To derive the volume per area, the data on availability are divided by the total area of the RBD. To derive the volume per capita, the data on availability are divided by population per RBD. This population dataset is not a product of reporting, but estimated calculations based on population density proxies (population NUTS level data disaggregated per km^2 and aggregated back at RBD scale based on the RBD area). In case that data at RBD scale were missing, data at country level have been used (also reported via the WISE-SoE reporting on Water Quantity) and have been divided by the total country population to obtain values of m^3 per capita.

Sources: Data come from multiple sources, and refer to a range of years as follows:

- RDB data

EEA-ETC/ICM WISE-SoE:	AT (2009), BE (2009), BG (LTAA), CY (2010), DE (2007), DK (2004), EE (2006), FI (2011), FR (2007), GR (LTAA), IT (2009, 2011), LV (2010), MT (2010), SE (2007), SI (2009), SK (2006), UK (LTAA)
Eurostat JQ IWA:	BE (2005, 2009),CZ (2009), HU (2008), LT (2009), LU (2009), NO (2009)
CIS EG WSD:	IT (2008)
Official national websources:	ES (LTAA), IE (LTAA)

- Country data

EEA-ETC/ICM WISE-SoE:	CH (2007), FI (2007), SI (2010),
Eurostat JQ IWA:	BE (2007), DK (2009), ES (2008), GR (LTAA), FR (2009), IE (LTAA), IS (LTAA), IT (LTAA), LU (2009), MK (2009), NL (2008), NO (LTAA), PL (LTAA),PT (LTAA), RS (2009), SE (2007), UK (2009)

Box 2.5 Climate change induced saline intrusion in the Belgian coastal area

(Drafted by Prof. Luc Lebbe, Department of Geology and Soil Science, Ghent University)

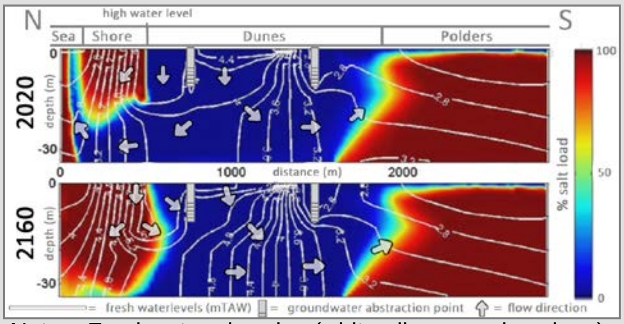
Figure 2.9 Belgian Coastal area

From the end of the 19th century onwards, the 65 km long Belgian coastal area endures an increasing pressure of tourism and urbanisation (Figure 2.9). For a few decades, groundwater resources are significantly affected as a result of reduced infiltration and increased water demand. The water supply has been secured for many years by drinking water abstraction in the dune area, but it is expected that combined effects of abstraction and climate change will result in elevated salinity levels of the dune and polder system.

Climate change includes both increased temperature and sea level rising, the latter causing additional saline intrusion and mounting of the freshwater layer. These stress factors may change the vegetation and freshwater availability. Hence, future decision-making should take into account effects of water consumption as well as potential adverse impacts on the water system.

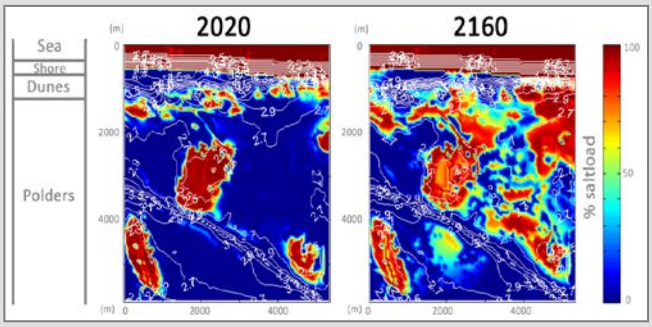
Decision-making must be supported by groundwater modelling and requires the monitoring of freshwater heads and groundwater quality. Models may provide information on the temporal and spatial changes of the flow directions. A first case of modelling shows the effects of a sea level rise of 90 cm per century at De Haan (Figure 2.10). Presently the maximum head is located between the shore and the groundwater abstraction point. Water from this head tends to flow toward lower heads, so the infiltrated water flows partially towards the shore and partially towards the groundwater abstraction. With a rising sea level, the maximum head shifts towards the sea, until it reaches the shore. Then all the infiltrated water in the dunes flows towards the groundwater abstraction point. At the high water shore line, the infiltrating salt water will start to flow towards the groundwater abstraction point. Compared to the current situation, salt water will be closer to the drinking water abstraction points and will reduce the production capacity in the future.

Figure 2.10 Vertical cross sections through the groundwater reservoir at De Haan for the years 2020 and 2160



Note: Freshwater heads (white lines and values) indicate the groundwater flow directions. The small blue top line in the polders is a small and vulnerable shallow freshwater layer.

Figure 2.11 Horizontal cross section through the upper layer of the ground-water reservoir near Ostend for the year 2020 and 2160



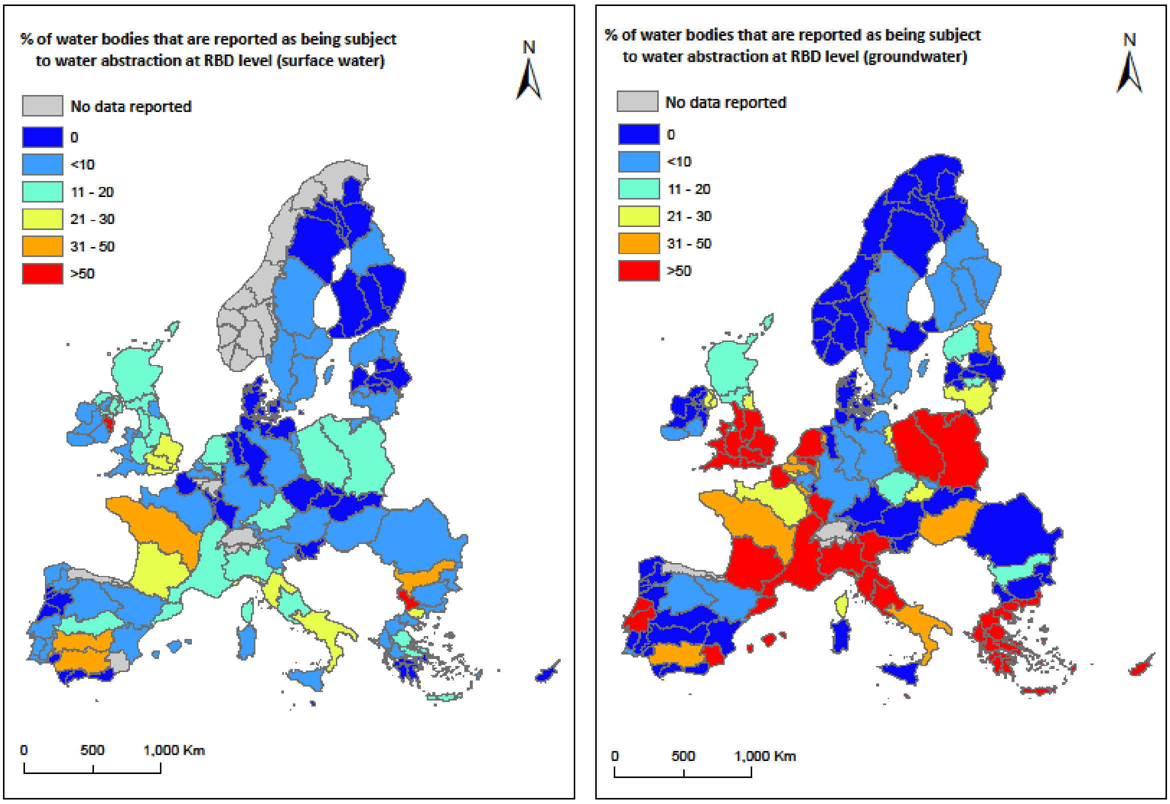
The second modelling case shows some areas of high saline values near Ostend. An increased sea level rise of 60 cm per century was simulated. Figure 2.11 shows the upper layer of the groundwater reservoir of which the top is currently mainly fed with fresh water, allowing agriculture in the polder area. Rising sea levels will put a stress on this shallow fresh water. Models show increased salinization in the future which will have an adverse effect on the pastures.

Policy and management require mitigation and adaptation measures to alleviate saline intrusion, to reduce salinity values, and to lower the fresh-saltwater interface in order to build up freshwater groundwater resources and to protect vegetation. Recent initiatives include the connection of the drinking water supply networks of the inland and coastal regions. Additional measures may be needed, such as the installation of a 'deep drainage system' and artificial recharge with re-used effluent water, obtained by a reverse osmosis of treated urban waste water. These effluents require additional treatment by reversed osmosis. The deep drainage system is a pumping technique to evacuate the deeper saline water in order to reduce the upwards salt water flow, allowing the restoration of the shallow fresh groundwater layer. This enables fresh water to recharge the groundwater reservoir to a greater depth than currently is the case.

Adding to the natural drivers, population growth can impact water demand either directly (e.g. drinking water consumption) or indirectly through the increased demand for manufactured goods, agricultural products, land etc. Human and economic activities, such as urbanization and land use change, tourism, industry and agriculture, apply pressures on the environment and threaten the quantity as well as the quality of water resources (e.g. excessive pumping, return flows with high concentration in agrochemicals, storm water runoff from urban areas, leakages from wastewater networks, etc.) (Blinda et al., 2007; Iglesias et al, 2007). The cause-effect relations between the anthropogenic drivers and their resulting pressure, expressed as variations in water abstraction and use in the different economic sectors, are not in-depth understood or explicitly analyzed, yet they are very important when it comes to designing effective mitigation measures which should tackle the drivers rather than just the pressures and the impacts.

The EU Water Framework Directive (WFD 2000/60/EC) includes an indirect analysis of the impact of anthropogenic activities on the status of the River Basin Districts (RBDs) through a process of identifying the significant pressures, abstraction being one of them, of surface and groundwater water bodies (Borchardt et al., 2003). Map 2.9 presents those RBDs that identified the surface and groundwater abstractions as a significant pressure in the WFD reporting, while Map 2.10 presents a classification of EU RBDs and Countries based on their total annual freshwater abstraction per capita, in order to visualize the range of the volume of freshwater abstracted annually across Europe. Cooling water abstractions has been included in the calculations, while hydropower is excluded as it is considered a non-consumptive use (it is recognized though that is creates pressures on the environment). As abstraction for cooling purposes in the production of electricity is a significant volume in some EU RBDs, and is usually released back to the system as returned water (with the exception of cases where e.g. evaporative towers are used), Map 2.11 presents abstraction for cooling purposes in electricity production as a percentage over the total freshwater abstraction. It is observed that this percentage is high in many areas in Central Europe and, assuming it is returned to the same system from where it was abstracted, it can alleviate the original abstraction pressure on the quantitative status of the water bodies. We need nevertheless to consider temporal stress conditions due to the lag time between abstraction and return of this quantity, as well as quality issues due to the deterioration of the quality of the returned volume (e.g. high temperature).

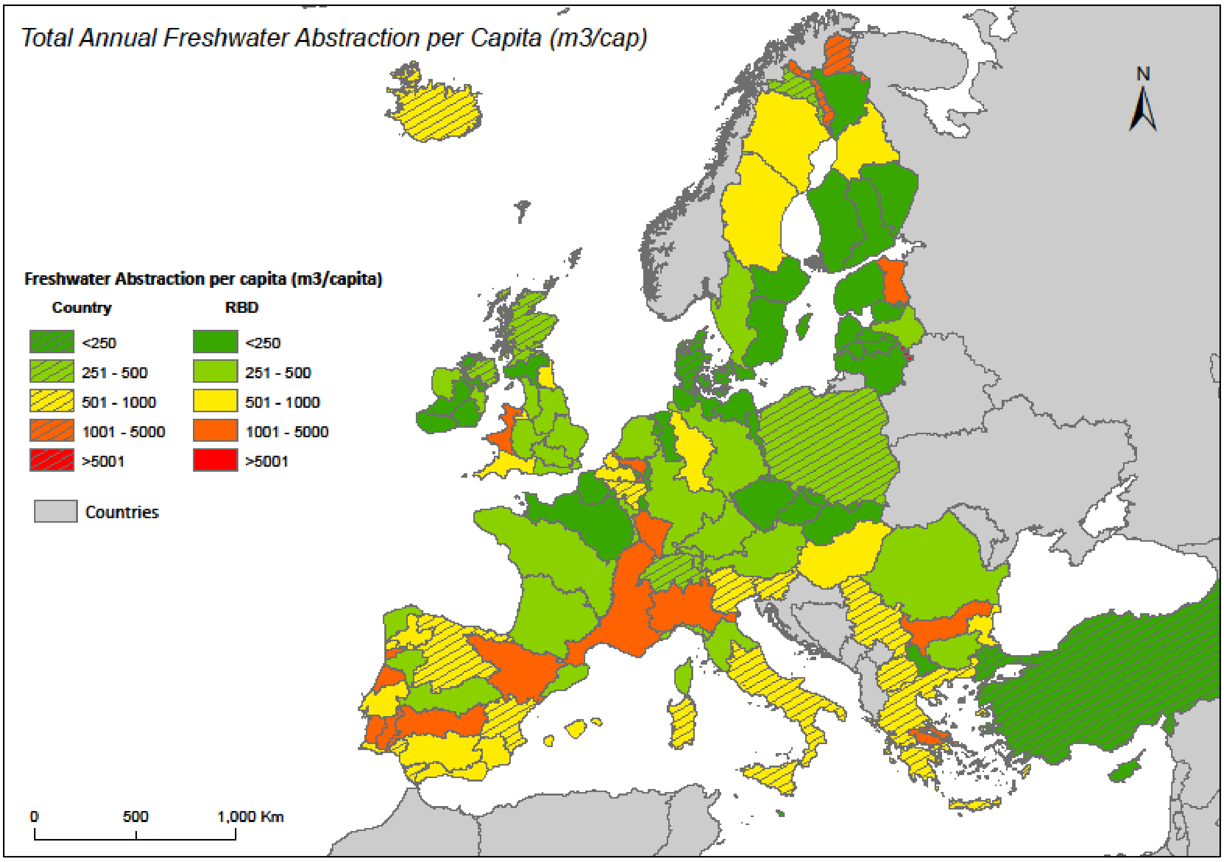
Map 2.9 RBDs that identified abstractions as significant pressure in the WFD reporting (left: surface water abstraction, right: groundwater abstraction)



Note: The maps demonstrate the percentage (%) of water bodies (surface and groundwater) within each RBD that have identified abstraction as a significant pressure in the WFD RBMP reporting.

Source: WISE-WFD master database, version of 13 June 2012

Map 2.10 Total freshwater abstraction (m^3/capita) in European RBDs, grouped into five classes.



Notes: To derive the volume per capita, the data on total abstraction are divided by population per RBD. This population dataset is not a product of reporting, but estimated calculations based on population density proxies (population NUTS level data disaggregated per km^2 and aggregated back at RBD scale based on the RBD area). In case that data at RBD scale were missing, data at country level have been used (also reported via the WISE-SoE reporting on Water Quantity) and have been divided by the total country population to obtain values of m^3 per capita.

Sources: Data came from multiple sources, and refer to a range of years as follows:

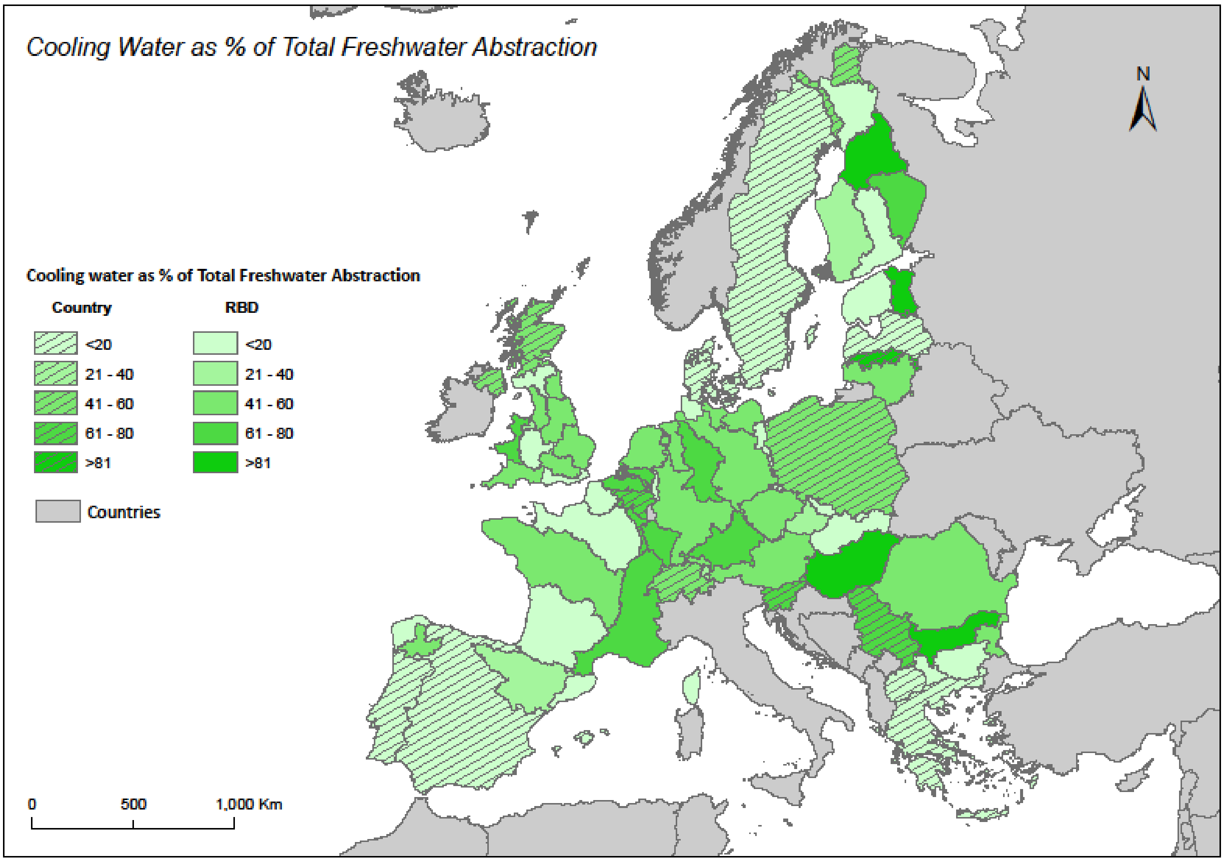
- RDB data

EEA-ETC/ICM WISE-SoE:	AT (2009), BE (2009), BG (2010), CY (2010), DE (2007), EE (2006), FI (2011), FR (2007), GR (2010), IE (2007, 2008), IT (2009, 2011), LT (2009), LV (2010), MT (2010), SE (2007), SK (2006), UK (2001)
Eurostat JQ IWA:	BE (2009), CZ (2009), HU (2008), IE (2008, 2009), LU (2009), NL (2008), RO (2009)
DG ENV WFD:	ES (2004, 2005, 2006, 2007, 2008), FR (2006, 2007)
DG ENV Questionnaires:	ES (2007), PT (2006)
CIS EG WSD:	IT (2008)

- Country data

EEA-ETC/ICM WISE-SoE:	CH (2007), FI (2006), SI (2010), UK (2001)
Eurostat JQ IWA:	BE (2007), DK (2009), ES (2008), GR (2007), IE (2007), IS (2005), IT (1998), LU (2009), MK (2009), PL (2009), RS (2009), SE (2007)
Official national websources:	TR (2010)

Map 2.11 Water abstracted for Cooling purposes in the production of electricity as a percentage (%) of the Total freshwater abstraction (m³/capita) in European RBDs (grouped into five classes)



Sources: Data came from multiple sources, and refer to a range of years as follows:

- RDB data

EEA-ETC/ICM WISE-SoE:	AT (2009), BE (2009), BG (2010), DE (2007), EE (2006), FI (2011), FR (2007), IE (2007), LT (2009), SE (2007), SK (2009), UK (2001)
Eurostat JQ IWA:	CZ (2009), HU (2008), IE (2009), NL (2008), RO (2009)
DG ENV WFD:	ES (2005, 2007, 2008)

- Country data

EEA-ETC/ICM WISE-SoE:	AT (2009), CH (2007), EE (2006), FI (2006), FR (2009), LT (2009), LV (2009), SI (2010), UK (2001)
Eurostat JQ IWA:	BE (2007), DK (2009), ES (2008), GR (2007), MK (2009), NL (2008), PL (2009), RS (2009), SE (2007)

Box 2.6 Groundwater Quantitative Status

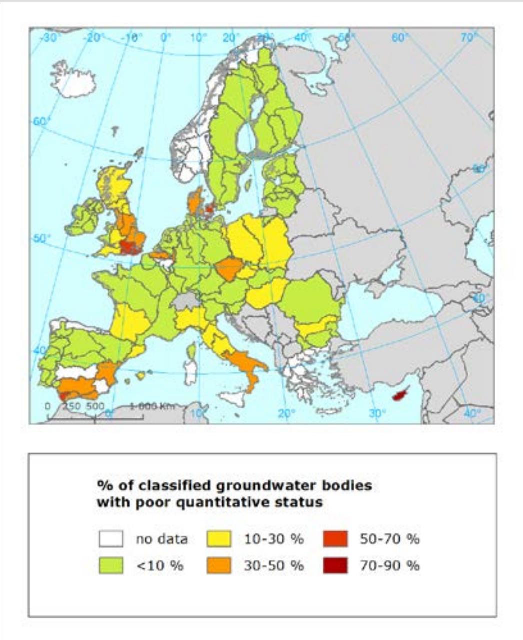
The definition of good groundwater quantitative status according to the WFD requires that the level of groundwater in the groundwater body is such that the available groundwater resource is not exceeded by the long-term annual average rate of abstraction.

From the total number of groundwater bodies reported in the WFD RBMPs, only 6.37% (782 out of 12,268 classified groundwater bodies) are classified as being in poor quantitative status in 2009. Only a few countries, namely Spain, United Kingdom, Belgium, Czech Republic, Denmark, Italy, Malta, have groundwater quantitative problems which are though mainly found in specific RBDs and not in the whole country, with the exception of Cyprus where approximately 70% of its Groundwater bodies are in poor status (Map 2.12). More specifically, the RBDs of Thames and South East in the United Kingdom, Zeeland in Denmark and Guadalete and Barbate in Spain have 50-70% of their Groundwater bodies in a poor status. The RBDs of Humber, North West and the Anglian in the

United Kingdom, Jutland and Funen, Guadalquivir, Andalusia Mediterranean Basins , and Jucarin Spain, Elbe in the Czech Republic, Maas River Basin District in Germany, Scheldt in Belgium and Southern Appenines in Italy have 30-50% of their groundwater bodies in a poor status, while 21 RBDs (scattered in the UK, ES, FR, IT, HU, PL, CZ, DE, BG) have 10-30% of their groundwater bodies in a poor status (Map 2.12).

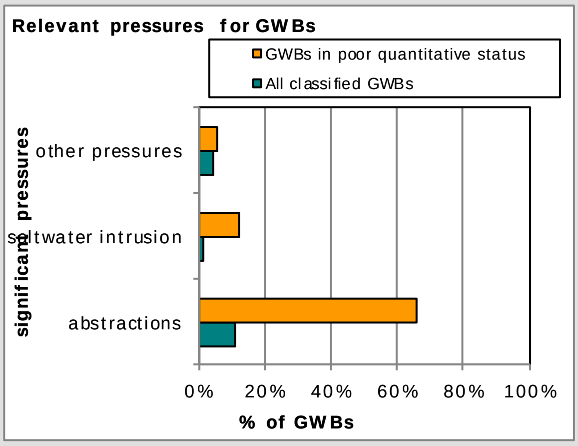
There are three significant pressures that are affecting groundwater quantitative status based on the WFD. The most commonly reported pressures are water abstraction (present in 11% of classified GWBs and 66% of GWBs which are in a poor quantitative status), followed by saltwater intrusion (in 12 % of GWBs in poor status). Finally other pressures are responsible for about 5% of the GWBs in poor quantitative status (Figure 2.12). It is open to discussion whether salt-water intrusion is a pressure or an impact. For the GWB quantitative status 2009, it was decided to report this as a groundwater pressure for the WFD.

Map 2.12 Percent of Groundwater bodies in poor quantitative status in 2009 per RBD



Data source: WISE-WFD database, version of 13 June 2012 (Kossida et al., 2012)

Figure 2.12 Relevant pressures of GWBs



Data source: WISE-WFD database, version of 13 June 2012 (Kossida et al., 2012)

The main response measures across Member States (as identified in the WISE-WFD and the compliance check databases) are grouped into 11 categories, varying from voluntary, to regulatory, legislative and financial, as presented in Table 2.5.

Table 2.5 Groups of measures and popularity

** this analysis is based on 15 RBDs that in 2009 were in poor quantitative status but the projections for 2015 are showing significant improvement*

No	Measures	Popularity
1	Promote and increase water use efficiency	Mostly applied (80-100% of the time)
2	Controls over groundwater abstraction - including registers of abstractions and requirement for prior authorisation of abstractions	
3	Controls of artificial recharge or augmentation of groundwater bodies - including a requirement for prior authorisation	

4	Monitoring: abstractions (installation of meters), piezometric levels	
5	Investment in water saving irrigation techniques	Selectively applied (40-53% of the time)
6	Management plans	
7	Awareness raising//advise/education	
8	(waste) water re-use and rain water management	
9	Artificial recharge (Increase resources by e.g. desalination)	
10	Science/Research/Risk and vulnerability Assessments	
11	Financial incentives / pricing policy for sustainable use (charges/fines/taxes for GW abstractions)	Least applied (13% of the time)

Source: Kossida et al., 2012

2.3 Experienced impacts at EU level

Impacts from drought and water scarcity can be classified as direct or indirect. Reduced crop and forest productivity, increased fire hazard, reduced water levels, increased livestock and wildlife mortality rates, and damage to wildlife and fish habitat are a few examples of direct impacts (Wilhite et al., 2007). Economic losses and social disruption are examples of indirect impacts. In Europe, water scarcity and droughts have affected most economic sectors and various ecosystems as selectively illustrated below:

- **Agriculture:** The 2011 severe spring drought and the consequent water use restrictions in irrigation affected the yield and the quality of many crops, such as wheat, barley, corn and grain crops, as well as livestock farming in **France** (Audran and McLeod, 2011). At the end of May 2011, Credit Agricole, historically the farmers' bank, was announced by the French Minister of Agriculture to provide 700 mill. € in loans to aid ranchers.

- **Navigation**: In the **Netherlands**, during dry periods, low river discharges causes restrictions in the inland navigation sector that disturb the cycle of transportation, loading and unloading leading to an increase of cost. Additional cost occurs due to the pumping of water required to balance the water level of rivers between two locks. According to the Netherlands national drought study the long-term cost due to low water levels in the navigation sector is estimated at 70 mill €, while the total cost can increase up to 800 mill. € in a year with extremely low discharge conditions (Projectgroep Droogtestudie Nederland et al, 2005).

- **Energy**: During the severe heat wave in 2003, extremely high summer temperatures accompanied by significant annual precipitation deficits (IPCC, 2008) and low stream river flow rates impaired the generation of electricity in more than 30 nuclear power plant units in Europe, due to limitations in the levels of cooling water discharge (IAEA, 2004). In order to be able to continue their operating activities some nuclear power plants got exemptions from legal requirements regarding these limitations. During nine summer periods between 1979 and 2007 the **German government** had to reduce production of nuclear power due to high temperatures of water and/or low water flow rates (Müller et al., 2007). The reduction of power output of the Unterweser nuclear power plant was reported at 90% between June and September 2003, while the Isar nuclear power plant cut production by 60% for 14 days due to excessively high temperatures and low stream flow rates in the river Isar in 2006 (Forster and Lilliestam, 2009).

- **Tourism**: In 2011 a brief web-based survey (Bruggeman et al., 2011a) was carried out in Cyprus in order to assess the vulnerability of tourism to climate change and water scarcity. Out of 320 hotels, apartments and guesthouses that received the invitation to participate a 7% actually participated. 83% of the participants mentioned that minor to major problems have occured during drought periods of the last 15 years. Half of them stated that they have installed water saving devices in their accommodation, such as water-efficient showerheads, dual flush toilets, water saving taps and toilet cistern bags. A large number of the participants also reported to train the staff and also inform their clients to use water wisely.

- **Groundwater degradation**: For over the last 40 years Groundwater overexploitation in the southern part of **Spain** has an enormous ecologic impact on the area (Ibáñez and Carola, 2010), related to significant lowering of groundwater tables, drying out of springs, degradation of wells and boreholes and saltwater intrusion. In the Ribeiras do Algarve River Basin in **Portugal** increased water demand for tourism and agriculture during the last decades has caused serious pressure on the area's environment, including aquifers' over-abstraction, salinisation and water resources' degradation.

- **Aquatic ecosystems**: According to a research conducted from June 2003 to March 2008 in the Mondego estuary in **Portugal**, drought conditions have a significant impact on fish communities causing disturbances in their behaviour and functions (Baptista et al, 2010). More specifically, during drought periods due to increased salinity inside the estuary and low freshwater flows the estuarine brackish habitats moved to more upstream areas, while in downstream areas new marine adventitious species were found. Moreover, freshwater species no longer existed inside the Montego estuary during drought, and lower densities were observed for most of the species.

- **Forestry**: In **Romania**, severe drought events (i.e. in 2007 and 2009) are reported to negatively affect forest areas causing changes in the area of several tree species and the boundaries of vegetation zones (moving North and West of the silvo-steppe), encouraging also the appearance of certain Saharian species in the South area of Romania (Lupu et al., 2010). Hills and plains covered with forests in areas of South and East Romania, such as Dolj, Olt, Galati, Braila, Ialomita, are proved to be very vulnerable to drought. This vulnerability not only affects the environmental balance but also has a negative socio-economic impact on the population.

Water scarcity and drought impacts may also be divided into economic, environmental and social. Specific examples for each category and for different EU countries are provided in Box 2.7-2.9. It can be observed that the most impacted sector is agriculture, followed by energy and public water supply. Economic and social impacts are high, as well as environmental. It is interesting to point out that the manufacturing industry is not reported to be widely affected.

Box 2.7 Economic Impacts (EIs) of Water Scarcity & Drought experienced by different European countries over previous years

<u>Definition</u>

EIs relate to different economic sectors such as agriculture, industry, energy, navigation, tourism and include:

a. Losses in production (crop & livestock production, manufactured goods, energy production etc.) and respective losses in the income generated by the various economic activities (e.g. tourism)

b. Increase in prices of food, energy and other products (as a result of the reduction in supply). Even the need to import goods may arise or to change the transportation method due to low water levels in rivers

c. Increased water prices due to compensating measures

d. Cost of drought mitigation measures (including water transfers, imports and other short term development options)

<u>Country Specific Examples</u>

– In **Slovenia** the direct economic cost of the 2003 drought (mainly loss of agricultural production and aid to farmers) reached 100 mill. € (Sušnik and Kurnik, 2005). According to the 2007 Slovenian Revision Report on Drought Mitigation Measures the total economic cost of drought in the years 2000-2006 was estimated at 247 mill. € ("86 Mill. € were allocated in the national budget and spent for recovery measures; 3 Mill. of € were allocated for preparedness measures"), (Gregorič, 2009).

– Due to the 2003 drought and heat wave **France** faced a 15% reduction in its nuclear power generation capacity for five weeks, and a 20% reduction in its hydroelectric production (Hightower and Pierce, 2008; Rübbelke and Vögele, 2011). Economic losses in agriculture and the energy sector were estimated at 590 Mill. € and 300 Mill. € respectively in 2003, and at 250 Mill. € and 270 Mill. € in 2005 (EC, 2007b). During 2006-2007, losses of 144 Mill. € were reported in the Savoia skiing area in the Alps. During the 2009 summer heat wave, due to cooling water shortages the nuclear power generation industry in France, the biggest European electricity exporter, faced a shortage of about 8 GW resulting in the import of electricity from Great Britain (Pagnamenta, 2009; Rübbelke and Vögele, 2011).

– In **Portugal,** during the summer of 2005, large amounts of crops were destroyed because of drought (60% loss of wheat and 80% loss of maize production) (Isendahl and Schmidt, 2006). Hydropower production was reported to be 54% lower than the average and 37% lower than in 2004. The costs of the 2004 and 2005 droughts on the public water supply, industry, energy and agriculture were 9, 32, 261 and 519 Mill. € respectively (EC, 2007b).

– The drought of 2002-2003 affected most of **Norway**, **Sweden** and **Finland** with a considerable decrease in hydropower production and a consequent increase in the price of electricity (Kuusisto, 2004). In Finland losses of 10, 1, 50, 17 Mill. € were reported for public water supply, industry, energy and agriculture respectively (EC, 2007b).

– In the **United Kingdom** agriculture was the main economic sector affected by the drought event of spring 2011. Field vegetables were reported to be affected in Yorkshire (later harvesting period, lower quality), yields of grazed and harvested grass for livestock production were reduced in parts of the south east, midlands and east of England, horticultural and cereal crops were also affected in some parts of southern and eastern England and voluntary restrictions on spray irrigators were implemented in the Fens. Due to the reduced production, feed prices raised and higher costs related to import had to be made (Environment Agency, 2011).

– In May 2011, river **Rhine** and river **Meuse** discharge was decreased by 58% and 68% respectively in comparison with the long term monthly average (Van Loon, 2011). As a result, the **German** Federal Hydrological Agency reported that ships on these rivers were forced to navigate at 20-50% of their capacity (Vidal, 2011).

– In **Romania** the drought of 2003 affected mainly agricultural production (i.e. wheat: 2500t/ha and rice: 0.5t/ha comparing to 7000t/ha and 10/ha respectively of a normal year) and the energy sector (the sole nuclear reactor in Cernavoda on the Danube River was put out of function due to low water levels) (Anon, 2009). Also the need to change the transportation method increases the price of products affecting almost the entire industrial sector.

– The total annual and investment cost of basic and supplementary measures proposed by the Water Catchment Management Plan for **the Maltese Inland** (MEPA and MRA, 2010) in order to mitigate quality degradation of water bodies and water deficit due to over-abstraction is calculated at 231.8 and 22.30 Mill. €, respectively.

Box 2.8 Environmental Impacts (EnIs) of Water Scarcity & Drought experienced by different European countries over previous years

Definition

Environmental impacts include:

a. Decrease of available water resources (jeopardized minimum vital flow)
b. Degradation of water quality (eutrophication, seawater intrusion etc.)
c. Loss of wetlands
d. Loss of biodiversity and degradation of landscape quality
e. Soil erosion and Desertification
f. Increased risk of forest and range fires
g. Changes in river morphology (terraces, gullies)
h. Ground subsidence

Country Specific Examples

– In **Lithuania,** during the 2002 summer drought, 123 forest and peat bog fires burst out in July and 374 in August (Sakalauskiene and Ignatavicius, 2003).

– In **Portugal** the 2004-2005 drought resulted in a water level fall in many reservoirs (two major reservoirs, Funcho and Arade, completely dried out), reduced river flows with a parallel degradation in their quality consequently affecting migrating species (e.g. lamprey in the Minho river), water table decline in aquifers, salt water intrusion in transboundary waters bodies (e.g. Tagus Estuary), forest fires and the removal of 220 tons of fish (De Marsily et al., 2007).

– The problem of salt water intrusion due to over exploitation is very common in several coastal aquifers of **Italy** (Antonellini et al, 2008). In the coastal areas in Sardinia, Catanian Plain, Tiber Delta, Versilia and Po Plain freshwater resources are becoming scarcer due to drought, over-exploitation and salinization.

– In the **Czech Republic** during the dry years 2003-2004 an increased defoliation of tree species was noticed, especially dieback of unoriginal spruce forests and Pinus nigra. Forests weakened by drought were more vulnerable and consequently attacked by Armillaria ostoyae and bark-beetles (Czech Republic National SD Report, 2008).

– In **Malta** because of high water demand resulting in over-abstraction, main groundwater bodies face the risk of failing to achieve the environmental objectives of the WFD (MEPA and MRA, 2010).

Box 2.9 Social Impacts (SIs) of Water Scarcity & Drought experienced by different European countries over previous years

Definition

Social impacts include:

a. Water shortage & interruptions (frequency, duration, extend) due to deficiency in public water supply
b. Population affected from water restrictions (levels and duration)
c. Public safety and Health
d. Rising conflicts between water users
e. Reduced quality of life
f. Inequities in the distribution of impacts

Country Specific Examples

– In **Portugal** during the 2004-2006 droughts, the cost for public water supply was 23.2 Mill. €, while 22,850 tankers were used in support of urban water supply in 66 municipalities with 100,500 inhabitants. The cost of the inconvenience to the inhabitants affected was considered to be significantly higher than the direct costs reported (De Marsily et al, 2007).

– In **Greece**, serious water shortage problems, particularly interruptions, affecting water consumers occur during irrigation season, when about 87% of total freshwater abstraction is used for agriculture (Isendahl and Schmidt, 2006).

– The 2008 extreme drought event left **Spain**'s reservoirs half empty. In particular, some reservoirs in **Catalonia** supplying 5.8 million inhabitants reached 20% of their capacity resulting in restriction in domestic water uses, such as swimming pools and gardening, as well as public water uses, i.e. fountains (Collins, 2009).

– The Tagus-Segura water transfer in Spain raised conflicts between the autonomous communities of Castilla-La Mancha and Murcia and also created tensions between **Spain** and **Portugal** concerning the flow regime (Isendahl and Schmidt, 2006).

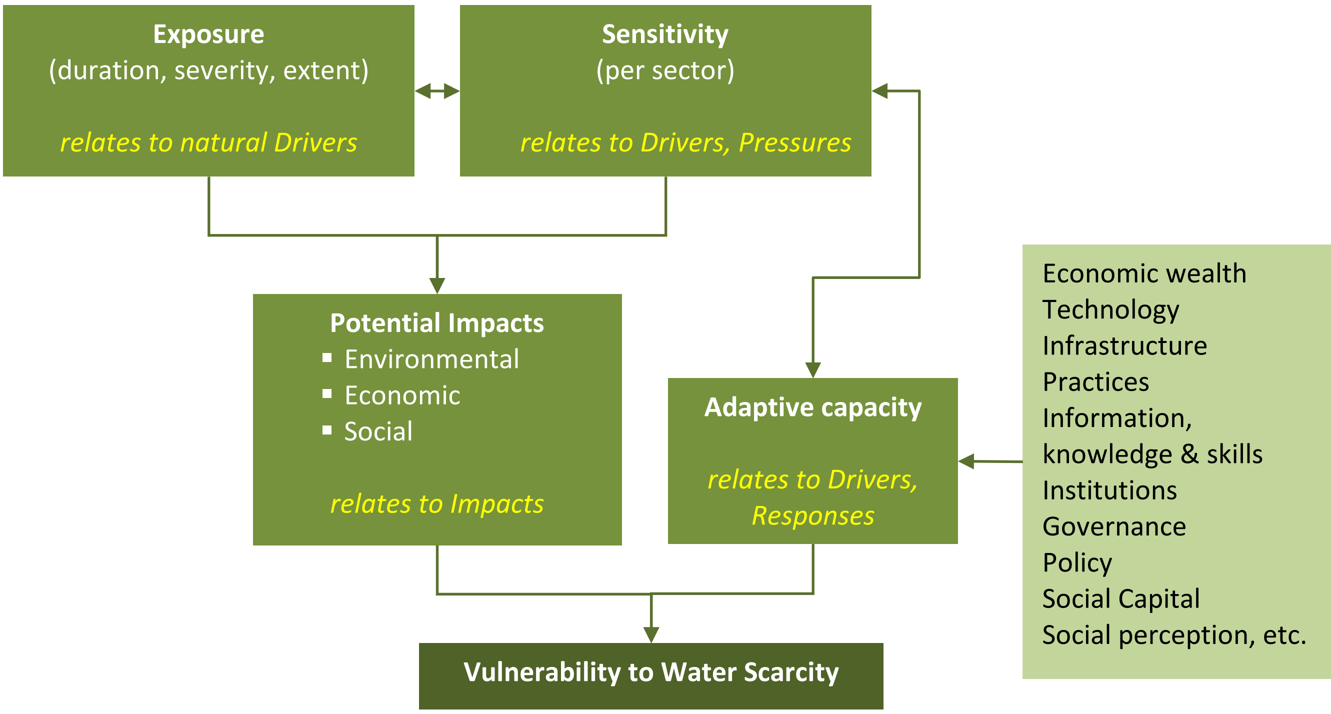
– During the 2011 drought restrictions on water use were imposed in several **French** administrative departments, 78 in total, which lasted for an exceptionally long period (18 weeks which is the equivalent of 1/3 of a year) (Ministere de l'Ecologie, du Developpement durable, des Transport et du Logement, 2011).

3 Addressing issues of vulnerability to WS&D in Europe – Selected case studies

3.1 EU vulnerability to WS&D – overview, issues and challenges

Assessing vulnerability to water scarcity is a complex multi-factor problem. The underlying exposure to stresses and threats may be similar even in quite different conditions, yet vulnerability is influenced by the priorities set, the economic and adaptive capacity of the affected area and population (sensitivity and margin of), the dynamic choices and response strategies adopted. Vulnerability to Water Scarcity and Drought is not yet fully tackled within the scientific community, and recent research has identified the need for a common definition and assessment framework which would support accurate communication and consistent analysis, eliminating ambiguous interpretation. In Europe, although vulnerability to floods has been defined and common risk assessment guidelines have been elaborated (under the EU Floods Directive), no analytical framework has been suggested for WS&D vulnerability. It is indeed true that the fact that: WS&D (a) operate on many scales (spatial and temporal) and levels (moderate to severe), (b) are a complex result of both natural and anthropogenic factors, (c) have a wide variety of impacts affecting many economic sectors, and (d) mitigation is highly dependant on the prevailing socio-economic conditions and adaptive capacity of a system, makes it inherently difficult to frame a single pathway into assessing the nature and degree of vulnerability. Nevertheless, as in all vulnerabilities associated with climate change, key parameters which hold a central role do exist and need to be coherently and scientifically integrated (i.e. exposure, sensitivity, impacts etc.). Figure 3.1 presents a schematic of the key parameters that influence vulnerability to water scarcity and their interplay (adopted from Ionescu et al., 2009) linking them to the DPSIR framework.

Figure 3.1 Conceptual schema of the components on water scarcity vulnerability



Source: adapted from Ionescu et al., 2009

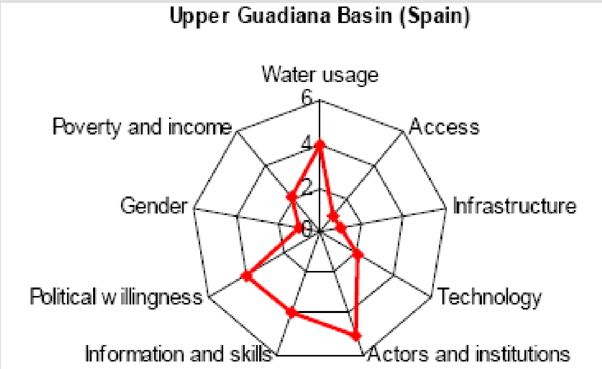
Box 3.1 Methodological approaches in defining Vulnerability to WS&D

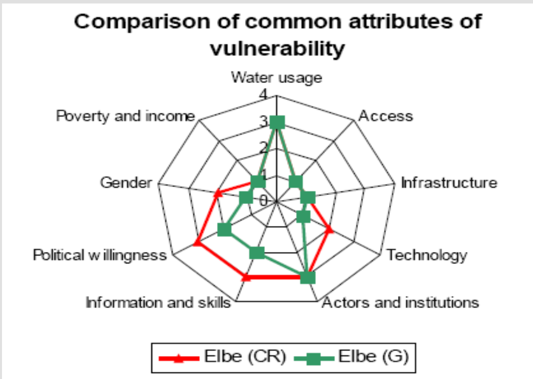
Using Vulnerability Profiles

NeWater FP6 project quotes that accurate statements about vulnerability are possible only if one clearly specifies (a) the entity that is vulnerable, (b) the stimulus to which it is vulnerable, and (c) the preference criteria to evaluate the outcome of the interaction between the entity and the stimulus (Downing and Bharwani, 2006). Furthermore, it emphasizes the significance of developing a formal framework which would ensure that representation of vulnerability in a systematic fashion (thus limiting the potential for analytical inconsistencies), would improve the clarity on the methods and results of vulnerability assessments, avoiding misunderstandings, and would form a solid basis to computational approaches and modelling. The NeWater project developed a Baseline Rapid Vulnerability Assessment (BRAVA) providing a baseline of exposure and resilience to stresses, and proposing a way to compare exposures, stresses and impacts across a range of geographic locations and scenarios of future conditions. The main components of BRAVA that are independently and jointly analyzed resulting in the vulnerability profile of a study area (Figure 3.2) are:

- Threats and stresses (surface and groundwater pollution, aquifer depletion, salinization, environmental degradation, economic uncertainty, agricultural dessication, potential industrial accidents, etc.)
- Exposure units/vulnerable groups (private farms, collective farms, private households, private fishermen, government agencies, tourist industry, power plants, recreation, navigation, wetland ecosystems etc.)
- Rated sensitivity (combination of the above two steps)
- Attributes of vulnerability (water usage, access, infrastructure, technology, political willingness, institutions, income etc.)

Figure 3.2 Vulnerability profile for (left) the Upper Guadiana Basin, Spain; (right) the Elbe RB in the Czech Republic and in Germany.



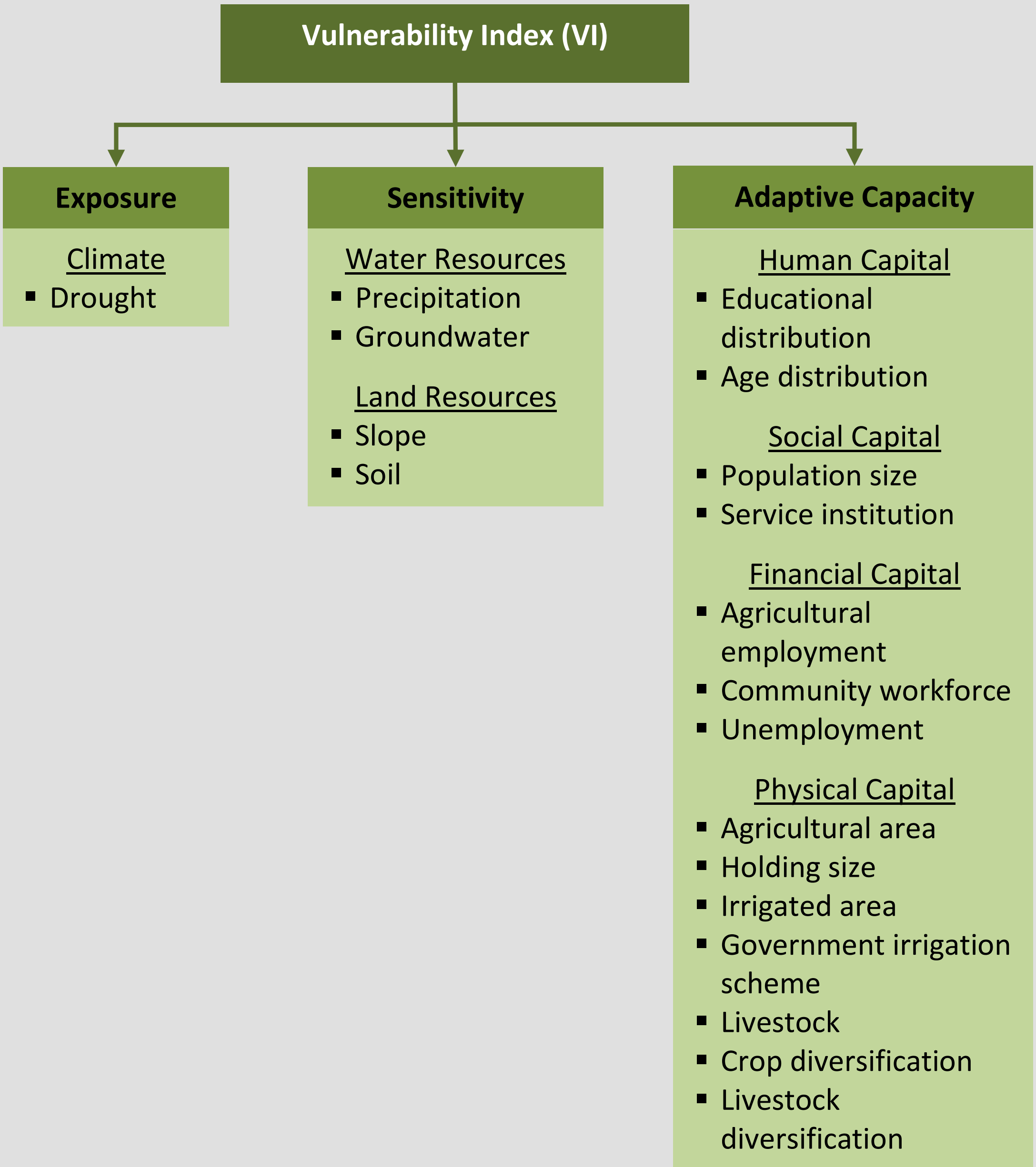


Source: Downing and Bharwani, 2006

Using a Blend of Indicators to derive Vulnearability Index

In the framework of the European Commission (DG Research FP7) project CLICO an approach regarding the vulnerability profile of rural communities to water scarcity and climate change is attempted (Deems, 2010). According to the research, the vulnerability of the region or country investigated is assessed by the so-called Vulnerability Index (VI). This index is primarily dependent on three parameters; exposure, sensitivity and adaptive capacity (Figure 3.3). Each of these parameters is described by indicators, which include sub-indicators. After the estimation of sub-indicators, the indicators are calculated resulting finally in the calculation of the VI. This method was applied for Cyprus, through a sub-division of 388 communities in order to produce a vulnerability map.

Figure 3.3 Indicators and sub-indicators for vulnerability assessment



Source: information drawn from Deems, 2010

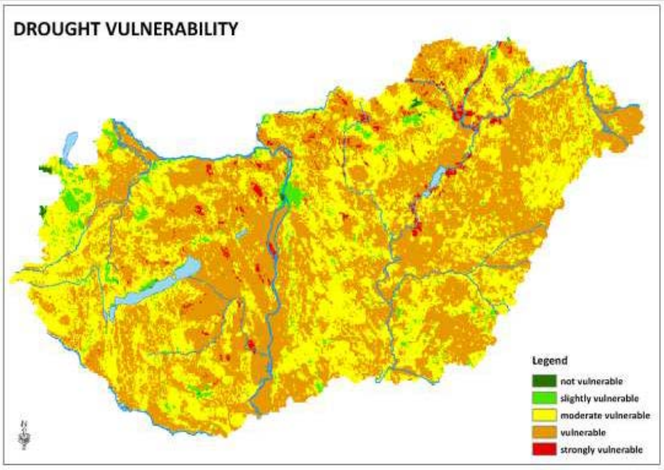
Using Weighted Multi-criteria Simulations

Another approach to vulnerability assessment has been implemented by the Drought Management Centre for South Eastern Europe (DMCSEE) which, in the framework of their DMCSEE TCP project co-financed by the European Union via the South East Europe Transnational Cooperation Programme, among their objectives, aimed at developing a methodology towards drought vulnerability assessment and mapping (for agriculture mainly) at a country level. Drought vulnerability maps for Croatia, Greece, Hungary (Figure 3.4), Macedonia, Montenegro, Serbia and Slovenia have been calculated from category maps which are made of selected necessary and optional parameters (i.e. indicators) widely measured, easily generatable and freely accessible for simplification purposes (Moring et. al., 2012). For the implementation of this method weighted multi-criterial simulation was used. The indicators were divided into two main categories (Slejko, 2010):

- Physical factors (precipitation, solar illumination-radiation, soil water-holding capacity and slope)
- Socio-economic factor (land use, irrigation)

After the definition of an appropriate weight parameter for each indicator, data were imported to the model on a GIS data base. The output of the described process was a raster vulnerability map scaling from 1 to 5 (from not vulnerable to highly vulnerable). The vulnerability maps are available on the homepage of the DMCSEE (http://www.dmcsee.org/GISapp/).

Figure 3.4 Drought vulnerability map of agriculture in Hungary



Source: Gregorič, 2012

3.2 Selected case studies addressing WS&D vulnerability per sector

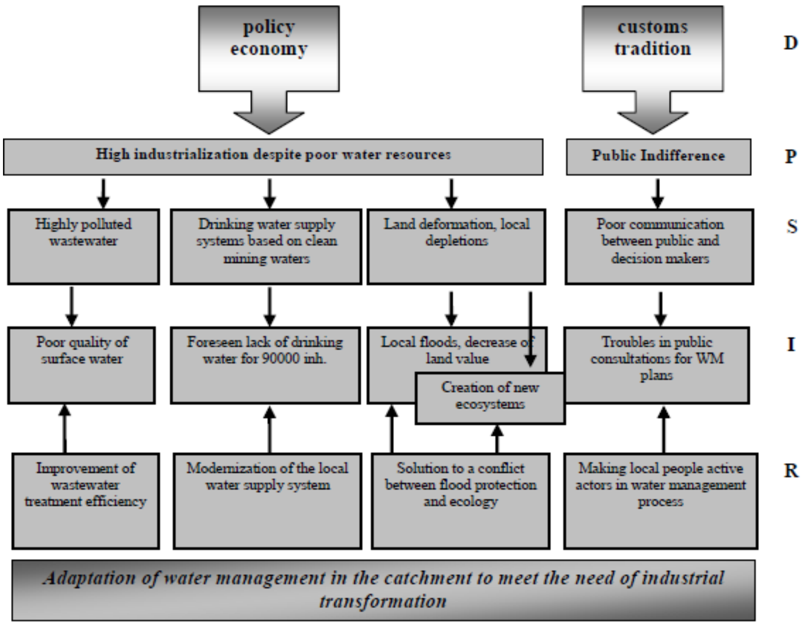
Different cases of vulnerability to water scarcity, for various European areas, are presented as exmples in this section with the purpose to rather highlight the diverse contributing factors as well as the strong influence of the prevailing regional conditions that can exacerbate or alleviate its magnitude. The vulnerability clearly relates to the potential (current and furture) impacts, the sensitivity and the adaptive capacity of the area in concern. The quantification though of these factors is still challenging since data present limitations, relevant indicators that can represent or proxy the various components are still not clearly defined, while the degree of influence among them (magnitude of their importance) is still to be determined.

3.2.1 Vulnerability to WSD due to industrial activities - Poland and Bulgaria

The Przemsza River Catchment is part of the upper Vistula river basin and is located in **Southern Poland**. The region is highly water stressed mainly due to overpopulation and industrialization (mainly zinc and coal mines and steel factories) (Wintgens et al., 2008). Over the decades, these anthropogenic activities have dramatically altered the quality and quantity of the region’s surface and groundwater resources. As a result, the majority of the surface water bodies are in danger of not reaching good ecological status by 2015 (Maciejewski et al, 2005).

A full DPSIR analysis (Figure 3.5) and an overview of the stress generated by the local industries are demonstrated in Table 3.1. It is apparent that the predominant pressure (high industrialisation despite the poor water resources status) along with the public indifference and poor stakeholders’ communication aggreviate the impacts (e.g. alterations in the flow regime: lowering of groundwater table in some areas due to mining works, increased volume but of poor quality at the points where wastewater is discharged) and make the local population more vulnerable (i.e. forseen lack of drinking water for 9,000 inhabitants). Adaptation measures are clearly needed, both on the technical side as well as the policy and governance practices, in order to reduce vulnerability and manage the associated risk. This requires a series of actions but prerequisites a close cooperation with industrial plants to obtain details concerning water consumption, characteristics of industrial installations and production processes etc. Thus, the task becomes even more challenging, since obtaining the data directly from industrial users of water, who are in conditions of competition, is far more difficult.

Figure 3.5 DPSIR analysis for the Przemsza case study



Source: Wintgens et al., 2008

Table 3.1 Stress generated by industrial users in Przemsza catchment

Water consumption and Wastewater treatment	hm^3/ year
Industrial water consumption	79.5
Groundwater abstraction	5.1
Surface water abstraction	21.7
Wastewater discharged (total)	263.9
Wastewater discharged directly to water or soil	261.5
Wastewater with substances very hazardous for the water environment	13.6
Total Wastewater treated	237.7

Source: data from Wintgens et al., 2008

Another industrially water stressed region is located in the **Iskar river basin**. The Iskar River is the longest river in **Bulgaria** (368 km), with the third biggest catchment area (8.650 km²). The test area includes Sofia, the capital of Bulgaria, and the main drivers and impacts of water stress have been identified as follows (Table 3.2).

Table 3.2 The main drivers and impacts of water stress in the Iskar River

Drivers	
Climate variability	Alternate periods of dry and wet conditions, hydrological regime over the period 1931-2000, precipitation anomalies
Water supply source for the capital - the Iskar reservoir	Single source of supply to 1.5 million citizens, in case of operational problem population will be exposed to water scarcity, high vulnerability
Former state water policies	Centralized decisions, low water price, lack of public awareness on water saving and water problems.
Socio-economic development of the capital in the transitional period	Boom in construction activities around Sofia, rapid population growth, intensive migration, industrial changes
Impacts	
Socio-economic	Conflict among the users, higher expenses for water per capita/unit, disturbed comfort of citizens
Environmental	Deterioration of water quality (increased electrical conductivity, concentrations of phenols and cyanides etc.)

Source: Information drawn from Wintgens et al., 2008

The Metallurgical plant Kremikovtzi AD is considered to be the biggest metallurgical plant on the Balkan Peninsula but also the major polluter in the area examined. It is a significant contributor to the Bulgarian economy (with near 2% of the GDP and over 10% of the country export for the EC). It was constructed in 1963 to support a complete metallurgical cycle and nowadays is posing great pressure in the area, both in terms of water quantity and quality. The water supply scheme is very complicated (consisting of both freshwater and reused water), while the total turnover industrial water is about 500-600 Mill. m^3/year (in clean and dirty cycles) and the freshwater consumption, which comes from 3 reservoirs, direct river and groundwater abstraction, amounts to 50-60 Mill. m^3/year. The two main water-related stresses that the plant poses to the area is the excessive use of water and its polluted emissions.

During a very dry season the monthly capacity of the available surface water resources will decrease significantly and may reduce the available industrial water down to 40% of the average consumption at normal conditions. As this would impair the manufacturing capacity, the water utilization was investigated in more details within the different technological units (so called “detailed water balance”) to identify the major bottlenecks (Dimova et al., 2007). The development of detailed balances and especially the comparison between the design values and the measured/calculated industrial water flows showed that the fresh water consumption in the blast furnace and the coke chemical plant is much higher than the design values – 45-20%. In almost all the plants the turnover water is much higher than the design values, which consequently results also in higher energy consumption. The comparison of the results with the EC recommendations on the best available technologies on water use (m^3 water/t product) shows that the water consumption is in the upper edge of the recommended range for most of the processes and there are opportunities for water saving (EC, 2001; Tarnacki et al. 2007). Exceptional is the cold rolling mill plant, where the water use per tone production is much higher than the recommended range. At the present state of water utilization in case of severe water shortage the operation of some technological processes should be suspended. Based on the analysis of water balance the following main problems were identified (Table 3.3).

Table 3.3 Problems related to the industrial water utilization in Kremikovtzi

No	Plant	Problem Identification	Negative effects
1	All	Poor performance of cooling towers – broken ventilators, distribution system in poor condition, problems with biological fouling	Unsatisfactory cooling, need for additional fresh water supply to achieve the necessary technological temperature.
2	All	The condensed water is not utilised and goes directly into the WWTP IRW	Increased hydraulic load to the treatment plant, unjustified utilization of fresh industrial water instead of condensate
3	All	Lack of appropriate automation of the operation of pump aggregates	Uncontrolled spillage of excessive water over the pump chambers, waste of energy
4	Blast furnace, steel melting plants	Poor condition of radial settlers; outdated equipment for slime removal and dewatering.	Excessive waste of energy and water for transportation of very liquid slime (98% water); necessity of greater storage areas for deposition.
5	steel melting plants	Outdated pipe system for turnover water and slime transportation.	Uncontrolled spillage of water, negative effect on the water supply of the gas cleaners
6	Hot rolling mill	Design and operation of high pressure pump system at the hot rolling mill.	Utilization of very large quantities of fresh industrial water (1600 m^3/h); Frequent hydraulic blows leading to serious failures of the pump aggregates

Source: Wintgens et al., 2008

Concluding, the focal problem in the test sites was identified as water stress generated by industrial users and the excessive utilisation of water above usual standards. On the one hand industry here is a key driving force causing a strong impact on water resources but on the other hand its condition and operation depends strongly on national policy and economy and related priorities. Optimisation of the industrial water use is a valid mitigation option, it requires yet:

- Thorough understanding of the industrial process, reliable data and analysis of the potentials for water saving, emission reduction, water-energy efficiency increase;
- Adequate monitoring and correlation of water quantity and quality issues for the proper and timely identification of threats and risks,
- Close cooperation with the industrial water users, joining forces for pilot testing and on-site validation which can result in solid proposals.

3.2.2 Drought effect on rivers' water quality with impacts on various economic sectors - Meuse River, Belgium

Meuse River in Western Europe is a rain-fed river, characterized by a highly variable discharge regime with commonly low discharges during summer and autumn, resulting in significant sensitivity to droughts (Berger, 1992). According to the research carried out in the framework of the project 'Risk analysis of climate change' (Van Vliet and Zwolsman, 2008) the 1976 and 2003 droughts had a severe impact on the water quality of the river Meuse concerning water temperature, dissolved oxygen concentration, eutrophication as well as concentrations of major elements, heavy metals and metalloids (selenium, nickel and barium). In terms of climate change, increases in the severity and frequency of drought episodes are expected to result in water quantity issues affecting important functions related to river flow, and increased degradation of water quality in the river that would negatively affect its sustainability and ecological value. Such issues may in turn pose limitations in cooling water discharges by power plants and reduction of water supply of sufficient quality for agricultural or domestic use. Especially for potable water, as the thresholds of concentrations of elements such as chloride, fluoride, bromide, and ammonium and water temperature are expected to be above the permitted limit during prolonged droughts, reductions in emissions of point sources during low-flow conditions will be proved necessary.

Concluding, drought impact on water quality can trigger stress conditions in different economic sectors due to failure in meeting specific quality standards. The main processes affecting water quality during droughts are similar for different rivers; however, the magnitude of water quality changes, and thus the vulnerability of the system, depends on river regime, catchment characteristics and human activities in the catchment, which is system specific. Still, some general conclusions can be made (Van Vliet and Zwolsman, 2008): rivers with generally low summer flow rates and significant chemical input by point sources, such as Meuse River, are expected to be more sensitive to drought episodes concerning water quality issues. This is mainly due to limited stream capacity for dilution and high warming rates of river water. On the contrary, rivers with relatively high summer discharges (e.g. rivers fed by snowmelt), are estimated to experience less intense water quality changes due to their larger dissolution capacity.

3.2.3 Urban sector vulnerability to WSD schocks - Barcelona Case Study, Spain

Between 2007 and 2008 Catalonia experienced a severe drought with multiple consequences on several productive sectors. Particular interest was given in the examination of the case of the **Metropolitan area of Barcelona** (where most of the Catalan population is concentrated) concerning both the severe impacts of the drought as well as the mitigation measures taken (Martin-Ortega and Markandya, 2009). The drought period lasted about 20 months (from April 2007 to January 2009) and the total losses are estimated at over 1650 Mill. € (for a one-year period, reference year 2008), almost 1% of the Catalonian GDP (see Table 3.4).

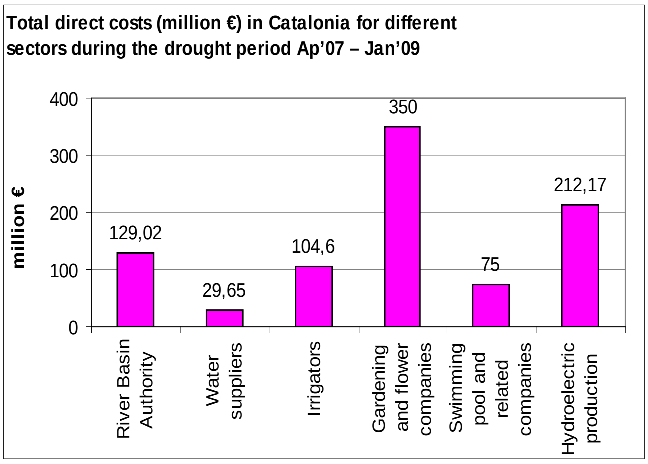
In Table 3.4 and Figure 3.6 direct and indirect costs of the experienced drought of 2007-2008 are summarised, as well as the estimated cost of non-market welfare losses. The first data come from an adaptation from Agència Catalana del'Aigua (2009), while the non-market welfare losses reflect a 'benefit transfer' approach from the Serpis River Basin (6th European Framework Project AquaMoney) to the city of Barcelona.

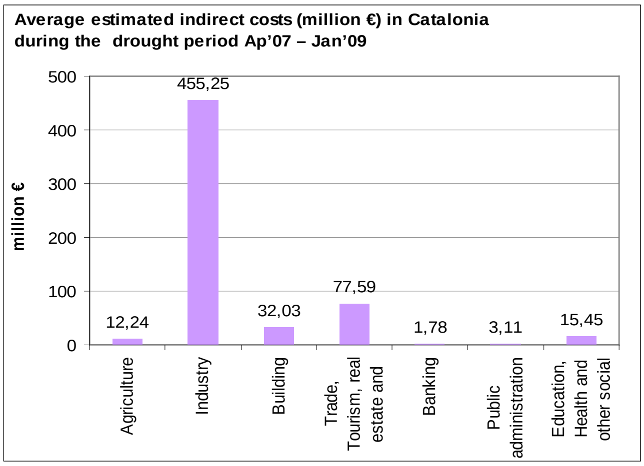
Table 3.4 Different costs of the drought event of Barcelona

	Average Cost (million €) during the drought period (Ap'07-Jan'09)	Cost (million € per year)	% Catalan GDP
Direct Costs	900.43	540.26	0.27%
Indirect Costs	597.45	358.47	0.18%
Non-market welfare losses due to household water restrictions (Social Cost)	990.32	594.19	0.30%
Non-market welfare losses due to environmental quality decrease (Environmental Cost)	279.60	167.76	0.08%
Total Costs	**2767.80**	**1660.68**	**0.83%**

Source: data from Martin-Ortega and Markandya, 2009

Figure 3.6 Total direct costs in Mill. € (left) and average estimated indirect costs (right) in Catalonia for different sectors during the 2007-08 drought period





Source: data from Martin-Ortega and Markandya, 2009

In response to the drought event of 2007-2008 and its negative effects, authorities were forced to take a variety of measures. In general, these measures can be classified into three main categories (Martin-Ortega and Markandya, 2009):

- <u>Emergency measures</u>: They include water demand control measures (i.e. restrictions in water use for irrigational, hydro-electrical, municipal and recreational purposes, public communication and participation campaigns, etc.) as well as supply measures that were not related to water distribution (i.e. water shipping).

- <u>Structural measures</u>: They refer to the improvement of old infrastructures but also the development of new ones regarding water desalination, water distribution networks and water treatment and reuse. These measures aim at a water availability increase in Catalonia up to 300 hm^3 by 2012.

- <u>Additional structural measures</u>: These are measures for the long-term conservation of water supply (i.e. re-opening of not-in-use wells and drilling of new ones, setup of water treatment plants).

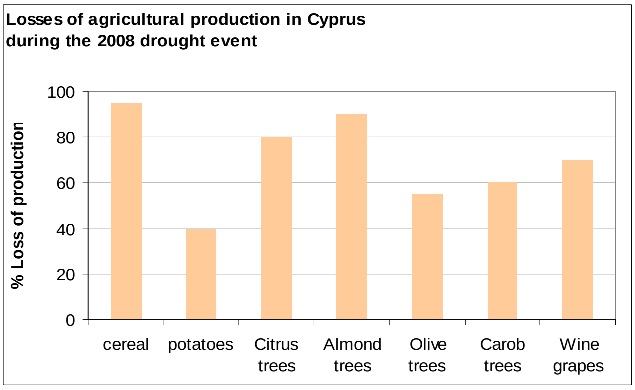
Concluding, Catalonia and especially the city of Barcelona in Spain were highly vulnerable to the 2007-08 drought event, with numerous sectors experiencing adverse impacts and the total direct and indirect costs summing up to about 1,400 Mill. €. Measures to both decrease/control demand and increase supply were adopted (including emergency actions such as water transfer) to mitigate the problem.

3.2.4 Vulnerability of Islands to WSD - Cyprus Case Study

As like on most islands, **Cyprus** is strongly dependent on rainfall for its water resources and thus highly affected by annual droughts. According to Cyprus Revised National Strategy for Sustainable Development (2010) it is estimated that since 1970 the mean annual rainfall has been reduced by as much as 15% resulting to a 40% reduction in the island's river flow rate. The total annual demand is around 254 million m^3, which is distributed to agriculture by 64.8%, domestic needs by 25.8%, industry by 9.4%, tourism by 2.8 % and finally to livestock-farming by 3.4%. It is also noticed that the annual consumption of potable water is increased by 2%. As the potential annual water consumption per person is 463 m^3/cap, Cyprus is classified among the countries of high water stress, even though great expenditure has been invested in water infrastructure, particularly modern irrigation systems, dams of a total capacity of 326 million m^3, and desalination plants. In addition, annual groundwater abstraction is estimated at 140 million m^3 (of which 30 million m^3 is over-abstraction), resulting in aquifer's being at risk of salinization and drying up.

In 2008 after a prolonged period of drought affecting mainly the agricultural (Figure 3.7) and domestic sectors, the island's water resources ended up extremely over-exploited (major dams such as Kouris, Yermasoyia and Dipotamos Dams dried out, groundwater has declined by 40% and aquifer salinization was detected) (Pouros, 2008). As an emergency measure to balance water shortage, 8 Mill. m^3 were imported from Greece. Total assistance provided to the farmers was estimated at 67.50 Mill. €, while the total cost for short-term emergency measures (actions taken in 2009 and 2010) to enhance domestic water supply was estimated at 287 million €. Finally, restrictions of water supply for both agriculture and domestic use were applied, limiting the supply to households to only 36 hours per week.

Figure 3.7 Losses of agricultural production during the drought of 2008 in Cyprus



Source: data from Pouros, 2008

In general, the main measures implemented by the government of Cyprus to tackle water scarcity issues can be summarised as follows (Hochstrat et al., 2010; EC, 2009b):

Infrastructure

- Installed desalination capacity at 112 m^3/d in 2008. Total capacity of all desalination plants in Cyprus is planned to reach 96 Mill. m^3/yr in 2013. The total cost for the Cyprus government to purchase desalinated water from private companies almost tripled in the last decade, from about €10 million in 1998 to more than €27 million in 2006.
- Domestic wastewater treatment for production of recycled water for irrigation and re-charge of underground aquifers (annual water recycling is estimated to reach 52 million m^3 by 2012)
- Improvement of public water distribution networks

Economic instruments

- Subsidies to water consumers for improvement and leakage minimizing of water supply networks (Figure 3.8)
- Water pricing

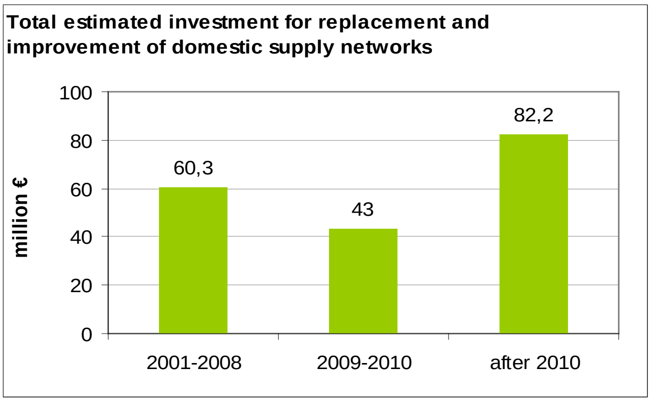
Educational measures

- Awareness raising campaigns (at a cost of €1.2 million in 2007 and 2008)

Legislative and Policy Measures

- River Basin Management Plan (in compliance with the WFD)
- Drought Management Plan
- Report on Water Policy
- Policy development and public consultation for water pricing

Figure 3.8 Investment for replacement and improvement of domestic supply networks from 2001-2010 in Cyprus



Source: Data from EC Maritime Affairs (EC, 2009b)

Concluding, in 2008 Cyprus was exposed to a severe drought event and demonstrated a high degree of vulnerability to WS with an increased sensitivity and impacts on many sectors. To mitigate these impacts a bundle of measures (emergency, economic, policy, educational) has been implemented, but the overall cost (water imports, infrastructure, agricultural production losses, subsidies etc.) was significantly high. It is however to be noted that islands and coastal areas in arid climates face additional challenges (i.e. the exploitable water resources may in reality be much less that the theroretical available due to direct discharges to the sea, technical solutions and water transfers may be much more costly to implement due their geographical location, etc.) and have an increased degree of vulnerability.

3.2.5 Increased impacts of WSD due to climate change in Eastern Europe – The Agricultural sector in the Czech Republic

Even though agriculture is not currently a main water consumer in the **Czech Republic**, according to the 2011 Report on Water Management in the Czech Republic (Ministries of Agriculture and the Environment of the Czech Republic, 2011) this situation can reverse if climate change is taken into consideration. Toman, Spitz and Filip (2008) from the Mendel University of Agriculture and Forestry have found that climate change will play an important role within the Czech Agricultural sector. In their research they examined two different climate change alternatives for drought and its impact on agriculture. In both alternatives an increase of 1.3°C in summer temperature was taken into account. In terms of precipitation, an increase of 3.6% was considered in the first scenario in contradiction to a decrease of 27% that was assumed in the second one. To determine the area of humidity deficient Seljanin’s hydrothermal coefficient HTK was applied and maps of HTK was extracted in order to estimate the extent of areas of various drought impact. According to the first alternative (slower climate change) 180,000 ha of agricultural land are expected to be affected by sub-arid conditions that will consequently result in an increase in irrigation in the Czech Republic by 40,000 ha as well as water demand by 57 Mill. m^3. Alternative 2 gives a much more unfavourable situation for the country, where irrigation should be applied on an area of over 1 million ha which means 35% of arable land. Water demand will be at 1,750 Mill. m^3.

Concluding, even though the Czech Republic is not currently using high amounts of water for the agricultural sector, climate change will play an important role. Future predictions show an increase in agricultural water demand of almost 60 Mill. m^3 in the conservative scenario, meaning an increase in the vulnerability of the agricultural sector to WS.

3.2.6 Economic development as a main factor contributing to increasing WSD vulnerability – The role of agriculture and tourism in the Murcia Region of Spain

The Segura basin (Figure 3.9) is located in southeast Spain and characterized by intense overexploitation of its water resources (Zimmer, 2010). In 1978, water transfer from Tajo to the Segura River Basin was initiated, increasing water availability in Segura to 1343 hm^3/y. However, there is still a water availability-demand deficit of 416 hm^3/y, which is met through groundwater over-abstraction. As a result, groundwater resources face the serious risk of depletion and degradation.

The Independent Community of Murcia (Comunidad Autónoma Región de Murcia) covers 59.3% of the Segura basin and 98.6% of its territory is drained by the Segura system. Traditionally, the agricultural sector is the major water consumer accounting for 89% of the total water demand. Due to the industrialization of agricultural production and the opening of the European and global market to Spanish products, irrigated area has tripled since 1953. Additionally, new water uses related to gated communities with golf courses of nine to 18 holes have been introduced in the recent years. This ever-growing kind of resort, usually referred to as residential tourism or "quality tourism", is estimated to demand much more water than the denser forms of tourist residences. These developments have also led to an increase in the population of Murcia with a consequent increase in the residential water use.

Figure 3.9 The Segura basin

Source: Hydrographic Confederation of Segura

Because of these new forms of water consumption and due to opposing perception of the value and correct use of water (on one hand water as a fundamental part of the ecosystem and on the other hand water as part of private economy that serves as means of growth) conflicts are raised between different social and administrative groups. A second transfer from the Ebro River was included in the National Hydrologic Plan in 2001 by the Popular Political Party of Spain, but was cancelled in 2004 after the opposite party won the elections.

Concluding, the Segura Basin and the region of Murcia in particular can be characterized as extremely vulnerable to water scarcity, especially due to the modernization and increase of the agricultural production. Most importantly, new trends in tourism (continuously increasing gated communities with golf courses) pose additional pressure on water availability and provoke conflicts to opposing stakeholders concerning the sustainability of water resources and economic development. Such developments, although economically attractive and beneficial for the community, make them simultaneously more prone to adverse effects on their ambient environment and more vulnerable to socio-economic impacts of water shortages when planned without thorough consideration of the water resources status and capacity.

3.2.7 Vulnerability of Protected Areas to WSD – Ecological damage in the Iberian Aquatic Ecosystems, Spain

"Las Tablas de Daimiel" National Park is a natural reserve in **south-central Spain** that covers about19 km^2 in the **Upper Guadiana Basin**. It is a Ramsar wetland and the core of the UNESCO Biosphere Reserve, called "La Mancha Húmeda". Due to groundwater overexploitation during the last few decades, mainly through illegal wells dug by farmers around the park (some of them reaching a depth of 100m), the aquifer that once supplied the wetland is now about 20m lower (Ibáñez and Carola, 2010). Moreover, the Guadiana River that used to cross the park has almost dried out.

The drought in combination with the fires that occurred in 2009 in the National Park worsened the already critical situation resulting in the deterioration of the wetland.

After the serious events of 2009, the EU gave a 10-week time limit to the Spanish Government in order to come up with measures to mitigate the ecological damage. Water transfer has been adopted as a temporary solution and in January 2010 water was diverted from the Tagus River Basin to the park through an underground pipe. Furthermore, intense rainfall in February 2010 contributed to the partial restoration of the depleted wetland.

Concluding, the protected area of ‘‘Las Tablas de Daimiel’’ National Park can be characterized as highly vulnerable to water scarcity and drought conditions. In order to maintain its ecological value and continue to provide a shelter to aquatic ecosystems permanent actions regarding water demand control, banning of illegal groundwater abstractions, and restoration of the wetlands are required.

3.2.8 Environmental Impacts of water abstraction for Hydropower generation - Upper Isar River, Germany

Since 1923, a major part of the **Upper Isar River (Bavaria, Germany)** has been diverted to Lake Walchensee through the weir in Krun for hydropower generation (Alpine Convention, 2009). The river is dammed between the regions Mittenwald and Krun and almost completely discharges into the lake. Because of this diversion, the river’s run-off has dropped significantly and consequently its bed load transport capacity has decreased (from 0.04 Mill. m^3 per year to 0.02 Mill. m^3). As a result, the region between Krün and the Sylvenstein reservoir, previously fed by the river’s bed load, face serious erosion problems. The floods of 2005 brought to light the necessity to remove part of the river’s bed load in order to protect the nearby villages. Moreover, the riverline landscape between Wallgau and the Sylvenstein reservoir is considered to be of great ecologic significance. It is a Natura 2000 site and is also part of the nature conservation area “Karwendel und Karwendelvorgebirge“. It is characterized by intense morphodynamic processes during high run-off periods altering the river course and the gravel banks which provide a habitat for protected species. Thus, for the preservation of these conditions a certain flow is required. Obviously, the river engineering measures necessary for flood control in Krün and Wallgau are in odds with the nature conservation requirements in the overall region. Thus, flood control actions that would not cause problems to the 2000 Natura areas and their protected habitat types are required. Moreover, an alternation in the minimum residual flow would seriously affect the management of the Sylvenstein reservoir.

To sum up, it is clear that for the sustainability of this region, a reconsolidation between the protection of the vulnerable to flood villages, the nature conservation of the protected area and the sustainable functioning of hydropower generation is needed.

3.2.9 Historic development of stress conditions in coastal aquifers – The impacts of over-exploitation and damming in the Akrotiri aquifer, Cyprus

The Akrotiri aquifer is located in the southern most part of Cyprus in the Eastern Mediterranean, and is part of the Akrotiri peninsula. It is the most important porous aquifer of Southern Cyprus with an approximate surface area of 45 km^2 and a thickness varying between 20 and 50m. The climatic conditions are typically semi-arid, with annual average precipitation rates of 450 mm/year and approximately 1300 mm/year of potential evaporation. Under normal conditions the aquifer is replenished by the Kouris River in the west and the Garyllis River in the east (Aquastress, 2009). These rivers drain an uphill area of approximately 365 km^2 covering a major proportion of the Troodos mountains where rainfall amounts are relatively high. Recharge of the alluvial aquifer also takes place by infiltration of rainfall directly falling on the plain as well as from the underlying Tertiary limestones along a major fault zone.

In the late 1930's heavy exploitation of the aquifer started due to the development of citrus fruit plantations. On average 14 million m^3 of groundwater were abstracted per year in the period 1940-1986. Due to growing water demand the Kouris dam was constructed in 1986, about 10km upstream of the Akrotiri aquifer, which reduced the fresh groundwater recharge. As a consequence, the natural recharge of the aquifer has been interrupted, since surface water was used in order to address the water deficit in the island. Milnes (2011) summarized the long term freshwater budgets for three periods (pre-1940, 1940-1986, post-1986) (Table 3.5).

Table 3.5 Long term water budgets for the Akrotiri acquifer for three historic periods

Water Budget component	**Pre-1940** (units in Mm^3/year) *period when no abstraction took place and the Kouris River still flowed*	**1940- 1986** (units in Mm^3/year) *period when abstraction was intensive and the Kouris River still flowed*	**Post-1986** (units in Mm^3/year) *period when abstraction was decreased but the Kouris River was dammed, no longer recharging the aquifer.*
Kouris river infiltration	15.4	15.4	-
Intiltration from precipitation	5.9	5.9	4.9
Subsurface recharge	4.2	4.2	5.1
Artificial recharge	-	-	1.1
Return flow from irrigation	-	4.5	0.8
Evaporation (forest and marshlands)	-2.5	-2.5	-2.6
Well extractions	-	-14.0	-7.9
Imbalance	**+23**	**+13.5**	**+1.4**

Note: The imbalances shown in the freshwater budgets indicate the annual net water volumes which are exchanged between the aquifer system and the sea.

Source: data from Milnes, 2011

The reduced recharge and increased groundwater abstraction has led to an imlbalance and an enhanced seawater intrusion, which became alarming by the end of the 1980s. Measures were implemented to decrease the groundwater abstraction and increase the recharge through controlled water releases from the Kouris and Germasogeia reservoirs, by using constructed recharge ponds. Occasionally limited quantities of water pumped from the Garyllis aquifer are also used for this purpose. In previous years, the general water table level into the plain stabilized below sea level. This slowed down seawater intrusion and groundwater salinisation induced by irrigation, yet salinisation continues at a slower pace. In the long term, water stress is expected to become even more serious due to a gradual decrease in the annual precipitation and an increase in the water demand.

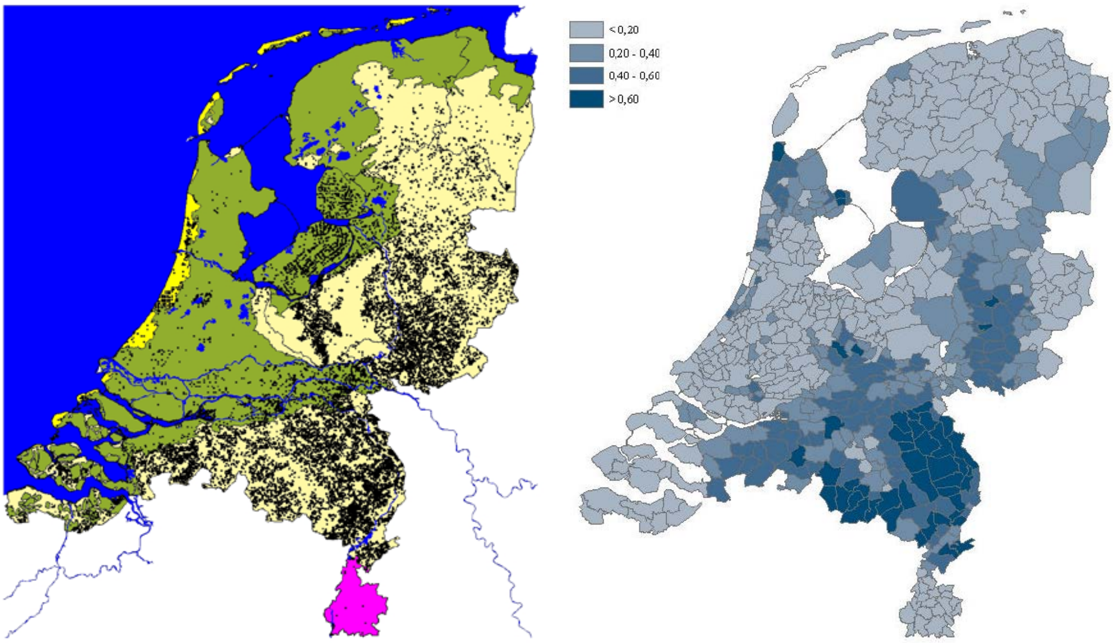
Concluding, this example is a nice illustration of the historic building-up of water stress conditions. The need to meet agricultural and growing urban demands led to the gradual development of human interventions (groundwater abstrcaction, damming) which reversed the hydraulic balance between freshwater and seawater and resulted in seawater intrusion.

3.2.10 Vulnerability of Small Water Bodies to WSD - Netherlands

On a yearly basis the water supply in the Netherlands is sufficient. However, water scarcity can occur, especially in summer periods when the amount of potential evaporation exceeds precipitation (De Louw, 2000). Although the Netherlands has a high water supply, the demands for water are also high. One of the reasons for this high demand is the intensive land use for agricultural practices. The increase in agricultural productivity in the past decades has been accompanied by higher water consumption.

To overcome periods of water shortages farmers use surface water and groundwater for irrigation. Irrigation predominantly occurs in the eastern and southern parts of the Netherlands (Figure 3.10) where there is less surface water supply available from the main waters, and is mostly used for grassland, corn, potatos, vegetables from field production and other crops. Soil moisture stress occurs more regularly, also due to the soil physical characteristics of the sandy soils. The groundwater levels show a higher fluctuation compared to the northern and western part of the Netherlands with low levels during the summer period. The total amount of abstracted water for irrigation (150-240 million m^3) is low compared to the total amount of water abstraction, and mostly originates from groundwater (~65-80%).

Figure 3.10 Location of abstraction wells from irrigation (left) and the fraction of irrigated lands compared to the total area of cultivated lands (right)

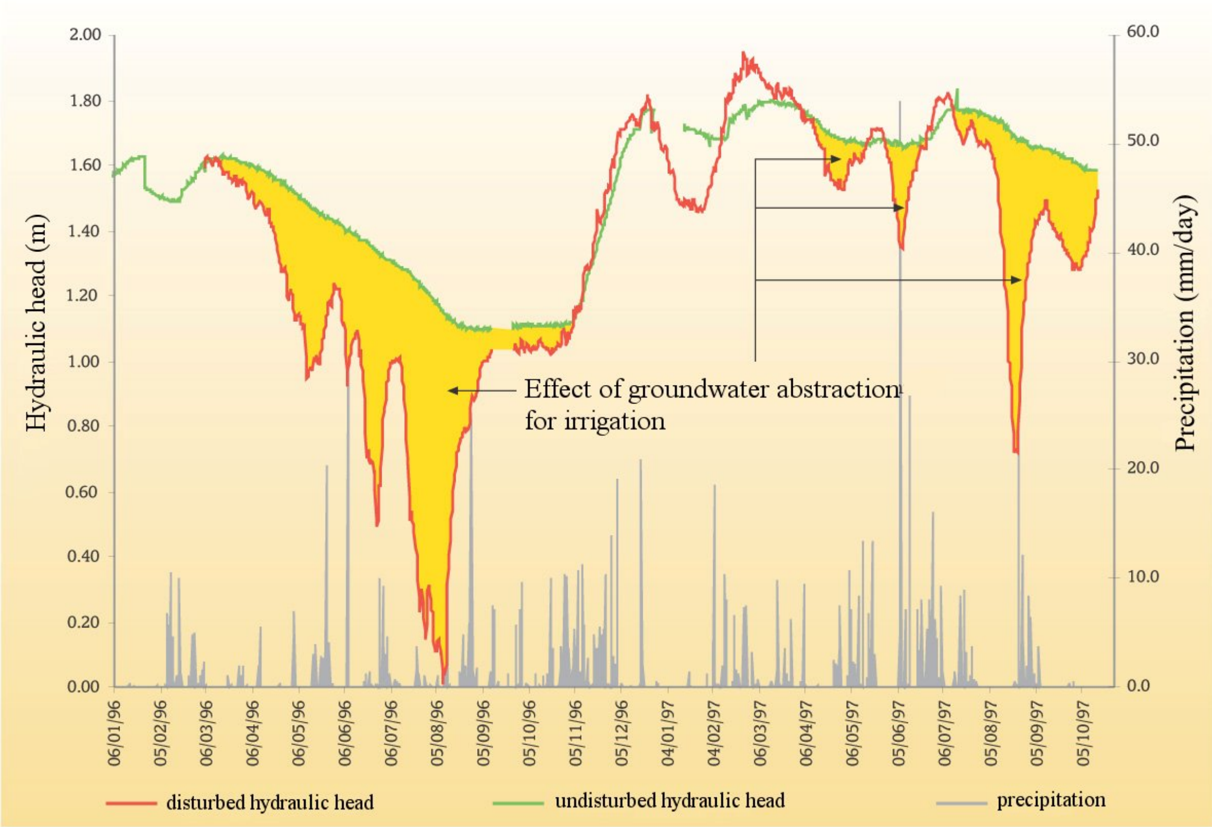


Source: De Louw, 2000

Impact of irrigation: The impact of groundwater abstraction depends on the geohydrological characteristics of the underground and subsurface, the depth and magnitude of the abstraction and the distance between abstraction and vulnerable receptors (e.g. groundwater dependent ecosystems). Although the total amount of abstraction for irrigation is small, the abstraction is concentrated in a small period of time when the water system is already stressed due to water shortages and when groundwater is important to maintain sufficient base flow for the rivers and brooks. For the province of Noord-Brabant in the south of the Netherlands the average amount of groundwater abstracted for irrigation is approximately 70 million m^3 as compared to 240 million m^3 per year for public water supply and industry. Yet, the abstraction amount for irrigation expressed per day during drought periods is 3 times higher than the abstraction amount for public water supply and industry.

The impact of abstraction for irrigation on the hydraulic head has been quantified (Figure 3.11). The hydraulic head can be lowered by up to a meter during the irrigation period. Sufficient hydraulic head is important for the base flow of small rivers and brooks as these systems are fed by upward seepage. This relatively cool, clean water is important for the survival of organisms in these aquatic ecosystems. Based on calculations with a groundwater model it was estimated that irrigation can cause a decrease in discharge of ~ 40 million m^3. For several catchments this is a reduction of 20% to more than 50% of the base flow. Climate change is expected to increase this problem as potential evaporation is increasing due to higher temperatures causing a lower water availability and higher water demand. One of the climate scenarios predicts warm summers with low precipitation amounts. If this scenario becomes reality, then the impact of irrigation will increase considerably.

Figure 3.11 Impact of abstraction for irrigation on the hydraulic head



Source: De Louw, 2000

Response Measures: Irrigation can be banned by regulation of the regional authorities to protect ecosystems. Since the dry year of 2003 this has occurred almost on an annual basis and more pronounced in the years 2006, 2007 and 2011 (9 out of 27 water boards). However, these measures are insufficient to cope with future problems. Therefore, several provinces and water boards have began to investigate the possibilities for a more structural adjustment of the water system to increase the water storage without compromising water safety. Measures like restoration of meanders in brook valleys, upstream water conservation through decreased or adjustable drainage and weirs are some examples of structural adjustments.

Concluding, groundwater abstraction for irrigation, even if it is restricted to relatively small volumes, can impact significantly on the small water bodies (especially in periods of drought) since due to lack of adequate hydraulic head the base flow cannot feed the small rivers and brooks with consequences in the survival of organisms in these aquatic ecosystems. Bans on irrigation can temporarily mitigate the problem, yet more structural adjustements may be required such as upstream water conservation, etc.

4 Scenarios and Projections for Water Scarcity & Drought in Europe

Scenarios provide the means to gain insight into plausible future developments. Rather than providing certain predictions of the future, they can help to gauge uncertainties in order to facilitate decisions that are robust under different possible futures (Moss et al., 2010). Scenarios are not forecasts and do not provide likelihoods of how the future might unfold, but can help us understand the uncertainties of future developments and facilitate the development of appropriate future policy response by looking at a wide range of different futures.

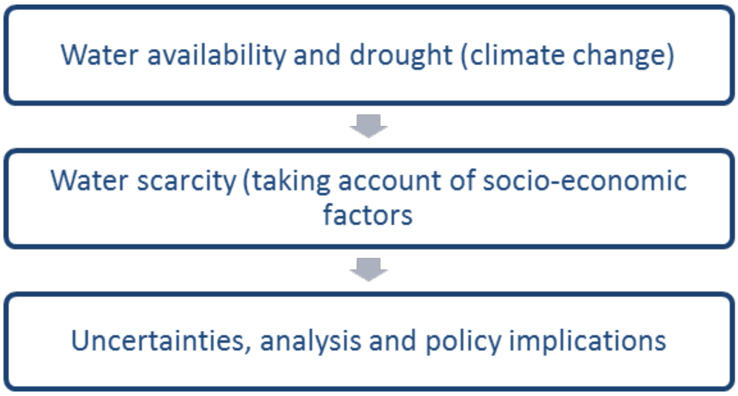
Increasing impacts of water scarcity and droughts in the coming decades are expected (EC, 2007a). The likely future occurrence of drought and water scarcity, in terms of intensity and frequency, and the severity of their impacts are dependent on climatic, meteorological, social, environmental and economic factors (Mishra and Singh, 2010). Relevant factors to be considered include existing infrastructure, land use, water management practices and institutions as well as public awareness. Analyses of the output of different scenarios can provide us with the bounds of what is probable in the future based on a combination of different variables consistent with our knowledge of the climate system and land use changes. Using scenarios helps to imagine what might happen and is therefore an important method for flexible mid-term and long-term planning.

4.1 Scenarios development

The development of scenarios can be seen either as highly technical (in the case of models) or highly subjective (in the case of qualitative scenario studies). Both characteristics present challenges for policymakers seeking to undertake evidence-based policymaking. Analyses of scenarios can help in agenda setting, identifying issues for policy attention and exploring uncertainties, and in developing appropriate policies (EEA, 2011).

The primary method to assess uncertainty and knowledge gaps is through an analysis of scenarios of a wide range of alternative futures (Schenk and Lensink, 2007; Nakicenovic et. al, 2001). Decision makers can make use of the output of scenario analyses in policy developments and responses. Ultimately, they should also contribute to informed decision making by allowing parties likely to be affected by the future developments to participate in the process. The use of scenarios also facilitates the exploration of possible impacts of different policy responses. The case studies presented in previous sections highlight the myriad factors that determine the occurrence of drought and water scarcity and the extent and severity of their impacts. While climate change can affect the occurrence of drought events and may intensify water scarcity in a region, climate change scenarios and their outputs can be used for the analyses of adaptation and vulnerability and to obtain estimations of future hydrological extremes through the use of land-use or hydrological models. The development of such scenarios takes the climate change projections as input based on which drought, water availability and water scarcity futures are developed. Finally, uncertainties and policy implications must be defined (Figure 4.1). Scenarios should be differentiated from short-term or even seasonal forecasts and predictions (Mishra and Singh, 2011), which in the case of water scarcity and drought generally allow for emergency response and interventions to reduce the likely impacts of these events or prepare for a temporary situation.

Figure 4.1 Overview of water scarcity and drought scenarios development



4.2 Climate change scenarios and drought projections

Climate scenarios provide the necessary input to make projections of changes in water scarcity and drought location, frequency and severity. By assuming different emissions scenarios and using different GCMs alongside different methods of downscaling, most climate model outputs point to a likely increase in temperatures over land in Europe. Higher temperatures lead to higher evaporation and more intense and frequent heat waves. Precipitation is likely to increase at the global scale, but there is considerable divergence and uncertainty at the local scale. At the same time decreases in ice and snow are evident in Europe. (EEA, 2012c). However, results indicate that land use changes and other factors have an important effect, especially at the regional scale (Paeth et al., 2009). A number of EU projects have focused on improving the projections of climate change, the quantification of uncertainties, and the implications of projections in terms of adaptation and mitigation. The PRUDENCE project (Prediction of Regional scenarios and Uncertainties for Defining European Climate change risks and Effects), which ran from 2001 to 2004, was followed by the ENSEMBLES project, which ended in 2009. Both projects have been devoted to model-based scenarios for climate change using different GCMs to run scenarios up to the terminal year 2100 based on SRES scenarios. The SRES scenarios explore the future developments of the global population, Gross Domestic Product (GDP), energy use, land use and emissions of greenhouse gases based on a number of socio-economic and technological considerations or storylines.

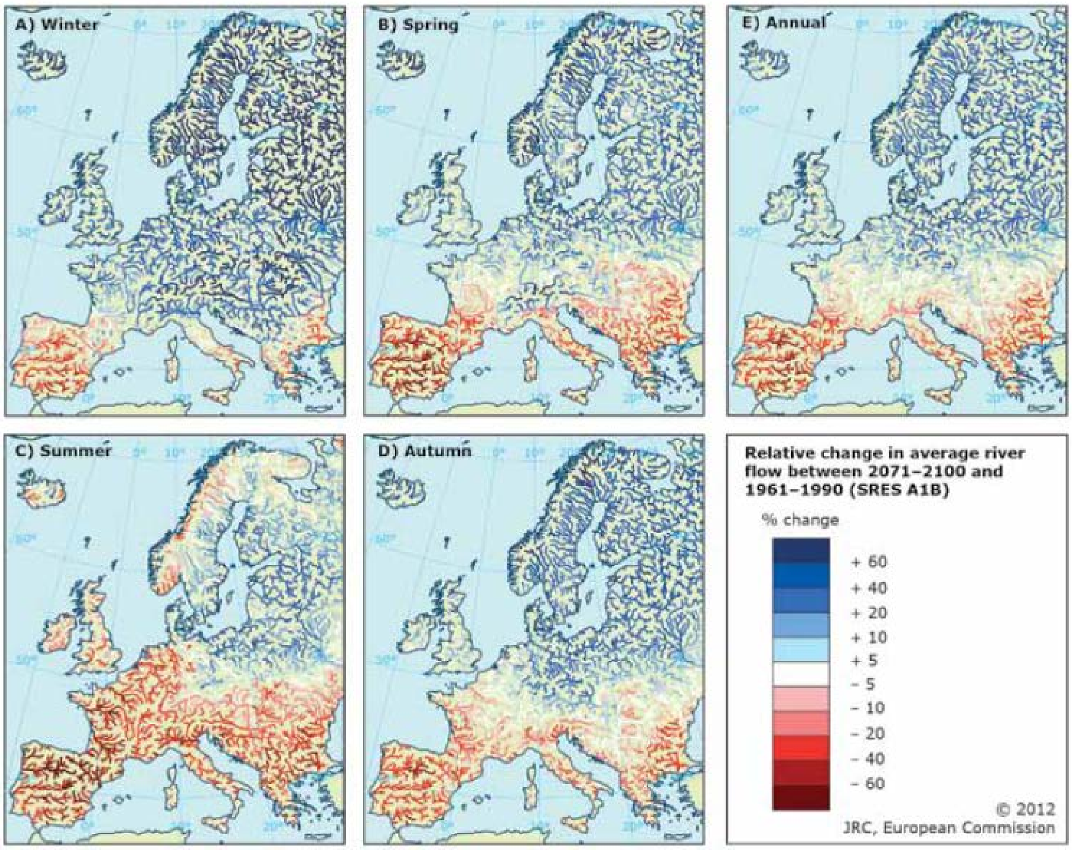
Capturing the uncertainty of regional precipitation change has proven difficult and is obviously directly relevant for water scarcity and drought scenarios (Maraun et al., 2010). A temporary decrease in average precipitation can lead to meteorological, hydrological and socio-economic drought, depending on the situation, location and intensity of the event. In the face of climate change, it is important to have an idea of the direction of change of drought events, their frequency and intensity. Recent studies suggest that climate change will likely lead to an increase of the frequency and severity of droughts at the global level, but there are significant regional differences. More severe and persistent droughts will be experienced in most parts of Europe in the frost-free season by the end of this century, but drought conditions will be less important under future climate conditions in the frost season in the most northern and north-eastern regions (Feyen and Dankers, 2009). This calls for a management approach that learns from past developments and considers likely future developments. Knowledge of the spatial and temporal occurrence as well as potential severity is crucial for appropriate management responses.

The WATCH (Water And Global Change) project compared drought projections derived from seven global hydrological models and land surface models driven by three different GCMs and two SRES scenarios. The results point to a possible increase in the number of drought events over the 21st century (Corzo Perez et. al, 2011). Drought events are projected in this exercise to be more dominant in the late part of the 21st century. The results of the three large-scale models show that America, Africa and Indonesia are regions with higher changes. The northern part of Asia appears to reduce the number of events although it should be noted that these regions have a weak representation in most of the global hydrological models. The average duration of droughts, using only the IPSL GCM input and the ensemble of hydrological models, shows an increase in the average duration of drought (threshold 80%); by the end of the century extreme drought events are defined as those of 35 to 69 days, whereas for the control period (1971-2000) this category was for events of 9 -13 days in duration. Drought predictions at the global level can give us a general idea of the direction of change in a particular area of the world and can also be used to identify sources of uncertainty. However, in order to inform policy development, stakeholders and others and to facilitate adaptation, planning and response, the spatial resolution of the information needs to be improved. This is achieved through a combination of input data at better spatial resolution and the use of different models.

Annual river flow is projected to decrease in southern and south-eastern Europe and increase in northern and north-eastern Europe (Milly et al., 2005; Alcamo et al., 2007; Dankers and Feyen, 2009). The LISFLOOD model (developed in the Institute for Environment and Sustainability, Joint Research Centre-JRC) has been used to simulate the hydrological behaviour in European catchments and obtain an indication of changes in the hydrological system. Using LISFLOOD, Rojas et. al. (2012) produced river flow projections. Strong changes are projected in the seasonality of river flows, with large differences across Europe. Winter and spring river flows are projected to further increase in most parts of Europe, except for the most southern and south-eastern regions, which would exacerbate the observed trend (EEA, 2012c). In summer and autumn, river flows are projected to decrease in most of Europe, except for northern and north-eastern regions where they are projected to increase (Map 4.1) (Rojas et al., 2012). The impact of river flow droughts is currently largest in southern and south-eastern Europe which will further increase with prolonged and more extreme droughts (Feyen and Dankers, 2009). Minimum river flows will not only decrease in southern and south-eastern Europe but will also decrease significantly in many other parts of the continent (e.g. western parts of Germany and the United Kingdom), especially in summer (EEA, 2012c).In snow-dominated regions, such as the Alps, Scandinavia and parts of the Baltic, the fall in winter retention of snow, earlier snowmelt and reduced summer precipitation is projected to increase river flows in the winter and reduce them in summer, when demand is typically highest (Beniston et al., 2011). A similar exercise was also carried out in the framework of the SCENES project. Low flow conditions were assessed through an analysis of Q90, which is the discharge that is exceeded by 90% of cases. Two scenario combinations were used, IPCM4 and MIMR, under the A2 scenario for the 2050s considering natural monthly river discharges, ignoring reservoir management and water use. The agreement of the two scenarios with respect to changes in monthly Q90 shows a decrease of Q90 for Mediterranean countries as well as for the UK and Ireland and the region by the Black Sea. The opposite is observed for Northern Europe and Russia.

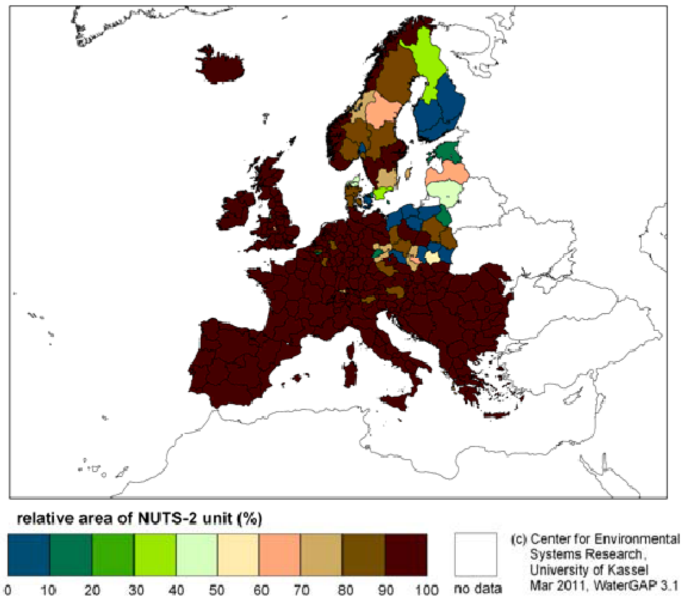
Complementing the above finding, the analysis of the ClimWatAdapt project shows an increase in drought risks across almost all of Europe (Map 4.2). The assessment was based on the median of LISFLOOD model results of the 11-member multi-model ensemble for the A1B scenario. All models show strong agreements in their estimates that by the 2050s a 50 year drought of today’s magnitude would return more frequently than once every 10 years (Florke et. al., 2011, based on the results of LISFLOOD). A relative share of more than 90% of the NUTS2 area affected by droughts is expected to occur across Europe, except Northern Europe, Poland and Baltic States, where the area share is projected to be less than 50% in about half of the NUTS2 units (Florke et. al., 2011, based on the results of LISFLOOD).

Map 4.1 Projected change in average annual and seasonal river flow



Note: Projected change in mean annual and seasonal river flow between the climate change scenario (SRES A1B, 2071–2100) and the control period (1961–1990). Simulations with LISFLOOD based on an ensemble of 11 RCMs.
Source: Rojas et al., 2012.

Map 4.2 Relative area of NUTS-2 units affected by droughts (based on the median of LISFLOOD results, 2050)



Note: Share of NUTS2 area affected by severe drought event; MQD10future < MQD50base in the 2050s. Median of ensemble drought results as calculated by LISFLOOD.
Source: Florke et al., 2011.

The recently concluded CIRCE project (Climate Change and Impact Research: the Mediterranean Environment) has been devoted to observe modifications in the climate variables and to detect regional trends. These observations have served to build a comprehensive set of data that describes the physical impacts of climate change and assesses the consequences of climate change for human society and ecosystems. The assessment has included a number of parameters from temperature and precipitation to saline output to the Atlantic and sensitivity to water stress in order to capture the complexity of the phenomena under study. These data were used to develop specific modelling scenarios for the Mediterranean, in terms of resolution, process and feedback inclusions. Given the aridity and recurrent water scarcity in the Mediterranean region a large part of the CIRCE project has focused on climate change impacts on water resources. The CIRCE project investigated the behaviour of precipitation for 2021-2050 under the SRES A1B scenario, using five different GCMs and RCMs. The results identified a reduction in winter precipitation over western North Africa and some parts of the eastern Mediterranean, as well as a general increase of the consecutive number of dry days (defined as the maximum number of consecutive dry days with precipitation< 1mm) over the entire Mediterranean basin. Also, results point to a possible reduction of spring precipitation over the Iberian Peninsula and a reduction of summer total precipitation in some areas of the Iberian Peninsula. Moreover, the Mediterranean coasts (although with relevant differences between the models) seem to be more exposed both to changes in the total and extreme values of precipitation.

4.3 Scenarios for future water stress evolution

Water scarcity is the point at which the demand for water by different users, including the environment, cannot be fully met by the available water resources supply. Therefore, evaluating likely future water scarcity involves also evaluating likely future water use, which is a function of a number of social, economic and environmental factors. Projecting water scarcity is a complex exercise with a wide range of uncertainties, particularly arising from the development of different socio-economic futures. Given the results of different scenarios and storylines, social systems and future policies will alter the natural impacts projected by the climate scenarios.

The SCENES project included stakeholders in the development of future water scenarios by asking them to provide qualitative and quantitative estimates of changes in factors affecting current and future water resources (Kok et al., 2011). These storylines built on the GEO4 scenarios, evolving along two axes, having a more global or regional orientation, and a more environmental or economical focus, and resulted in four plausible scenarios as summarised inTable 4.1.

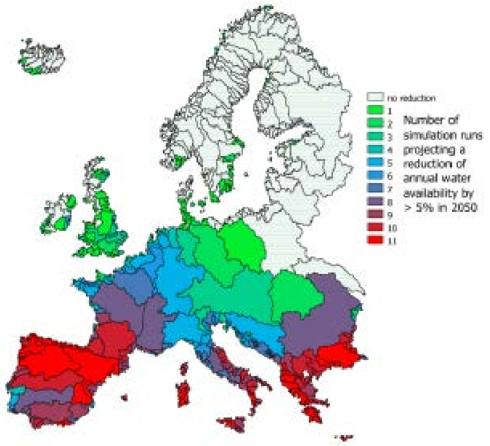
The DG ENV ClimWatAdapt project (Florke et al., 2011) assessed future water stress conditions based on climate and socio-economic projections of the ENSEMBLES and SCENES projects. For the vulnerability assessment, only the EcF (Economy First) and SuE (Sustainability Eventually) scenarios were analyzed (because these two scenarios span the broad variety of the SCENES scenarios) as the median of an ensemble of LISFLOOD simulations that are driven by projections of climate based on the A1B scenario for 11 different GCM-RCM combinations for the period of 2041-2070. The hydrological modelling and water balance results were used to assess the water availability and withdrawals (Map 4.3 and Map 4.4) within a basin for the 2050s (2041-2070) and compare it to the 2005 baseline year in order to evaluate the magnitude of change. Water availability is predicted to decrease in Southern Europe where 10 or 11 out of 11 model simulations predict reduced water availability for large parts of Spain, Portugal, and Greece (Map 4.3). In Northern Europe, water availability is probably increasing, while none of the models project decreasing water availability in most parts of Northern Europe (Florke et. al., 2011). Water withdrawals (as a result of future water use driven by socio-economic and technological changes) are expected to increase in Europe by 2050 under the EcF scenario with the exception of river basins in Denmark, the Iberian Peninsula, Italy, Greece, Cyprus, and Turkey, while for the SuE scenario a decrease in total water withdrawals of more than 25% is simulated for all of Europe (Map 4.4). The main reason leading to this decline in total water withdrawals are technological innovations designed to use water more efficiently as well as an increasing commitment to conserve water (Florke et. al., 2011). Looking at the future water use per sector (as a result of the EcF and SuE simulations) agriculture is the dominant user in Southern Europe while cooling water dominates in Western Europe (Figure 4.2). This share increases under the EcF scenario, whereas the cooling water proportion almost diminishes in SuE due to the assumption that all once through cooling systems in Europe will be replaced by tower cooling. The same conclusions can be drawn for Eastern and Northern Europe, where in fact no dominant water use sector is apparent (Florke et. al., 2011).

Table 4.1 SCENES project storyline descriptions

Storyline/ Scenario	Description
Economy First (EcF)	Globalisation and liberalisation are embraced, while technologies and innovations spread quickly. Additionally, economic growth is high yet unequal. In short, there are more opportunities for those that can afford it. Moreover, multinational companies dictate environmental standards and basic research struggles with lack of funds. As a result, all river basins are further from WFD compliance than in 2010; water quality decreases in large parts of Europe. Water pricing, however, becomes an important mechanism. After 2030, governments are under severe pressure to address environmental problems and new balance with more regulations emerges.
Fortress Europe (FoE)	A high number of crises (energy, financial, and climatic) result in an increasing instability and terrorist activities throughout the world, as well as in Europe. Subsequently, Europe closes its borders and concentrates on a series of security issues, including a central goal on self-sufficiency. Cooperations are difficult and alliances change, but perceived threats keep the EU together. The WFD becomes the Water Security Framework Directive with much less public participation, to tackle the increase and intensification of water conflicts. Water policies focus on water demand, which is largely satisfied by 2050.
Policy Rules (PoR)	There is a stronger coordination of policies at EU level, but policies become slowly more ineffective. As a result, ecosystem services begin to deteriorate very significantly. Until 2030, the EC becomes increasingly disappointed in the level of WFD compliance; issues of water quality and quantity are generally ignored; while there are emerging and increasing pressures on water resources. After 2030, climate change hits hard and changes public apathy, leading to WFD compliance that is higher than ever. By 2030, public participation increases, leading to local government support. By 2050, Europe is at the forefront of a new socio-economic paradigm of public/private partnerships and leads a global shift in this direction.
Sustainability Eventually (SuE)	Europe transforms from a globalised, market-oriented society to an environmentally sustainable one, where local initiatives are leading. Landscape is the basic unit and there is a strong focus on quality of life. Initially, change is governed by top-down policies ("quick change measures"), which later become redundant as bottom-up "slow change measures" take effect. The process is kick-started by a series of extreme events. In 2050, the current EU has been replaced by two alliances, water-poor and water-rich countries, i.e. environmental issues are dealt with by eco-region and not by country. Overall water demand has structurally decreased; widespread water policies are implemented; and before 2015 the WFD is updated and made more powerful.

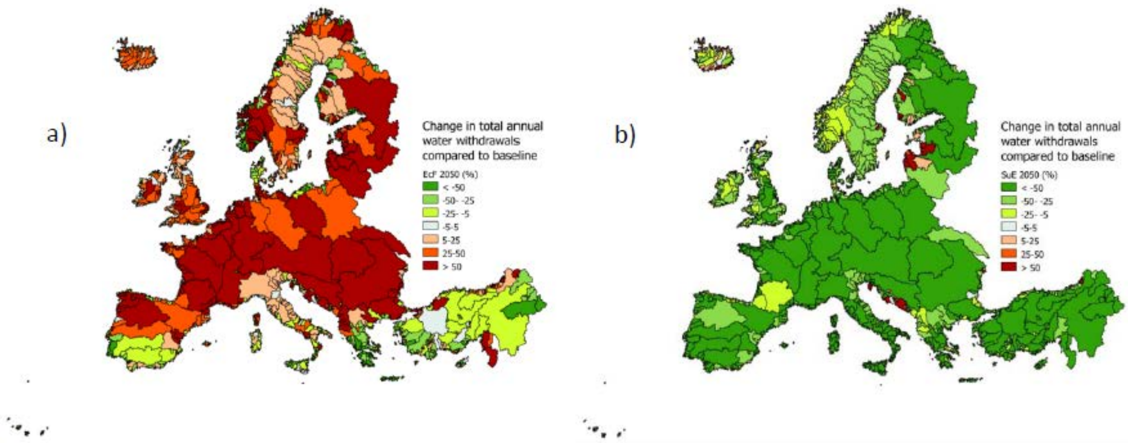
Source: Kok et al., 2011, SCENES.

Map 4.3 Change in the annual average water availability in the 2050s



Note: Agreement in the direction of change in the annual average water availability on a river basin scale for the 11 climate models forced by the A1B scenario used to drive LISFLOOD. The map shows the number of hydrological simulations that showed a considerable (more than 5% relative to the baseline) decrease for the year 2050.
Source: Florke et al., 2011.

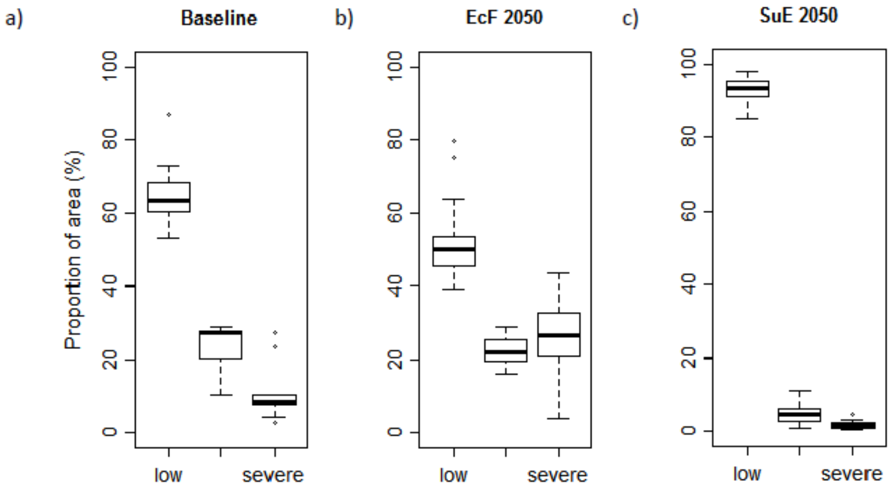
Map 4.4 Change in total water withdrawals compared to the base year. (a) Ecf scenario and (b) SuE scenario in 2050.



Source: Florke et al., 2011.

Water withdrawals-to-availability ratio within a basin was also computed for the 2050s (2041-2070) and was compared to the 2005 baseline year in order to evaluate the magnitude of change, both annually and seasonally. For the annual assessment, the area under severer water stress increases (+15%) under the EcF scenario, particularly in south-eastern Europe but also in central and western Europe, while a considerable decrease (-5%) in the area under severe and mid water stress is apparent for the SuE scenario. When analysing the results for summer, the area under severe water stress increases for both EcF and SuE, however, the difference to the annual exercise is far more pronounce for SuE (this is particularly apparent for the Iberian Peninsula and the Balkan countries) and relates to the different water use projections.

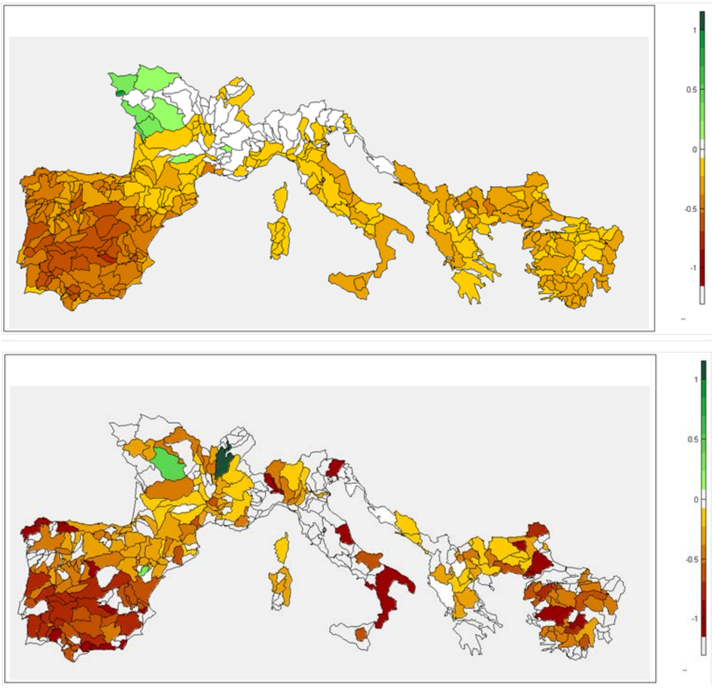
Figure 4.2 Box-Whisker-Plot of the fraction of Europe's area covered by river basins with low, medium and severe water stress



Note: Water stress is expressed by the withdrawals-to-availability ratio for a) the baseline and the scenarios b) EcF 2050 and c) SuE 2050. Low stress values <0.2, medium stress values 0.2-0.4, severe stress values >0.4. Source: Florke et. al., 2011.

Regional models offer the possibility of considering water demand in greater detail than European-wide analyses. The WAPA model, which was used in the CIRCE project, can be used to evaluate water availability for a set of specific demands under different conditions (Iglesias et al., 2011; Quiroga et al., 2011). WAPA computes water availability and reliability for urban and irrigation demands considering a fixed amount of urban demand (assuming 300 lt/capita/day), which is met first, and a variable amount for irrigation demand. Figure 4.3 shows the per-unit change in runoff for 2021-2050 with respect to the control scenario as well as the per unit change in water availability considering urban demand as primary. In many European basins, the proportional reduction of water availability is larger than the reduction in mean annual runoff, implying that the use of water for other purposes such as irrigation would be curtailed more than the reduction in annual runoff considering the priority of urban demand (Iglesias et al., 2011; Quiroga et al., 2011). A regional approach is also being considered in the ongoing DG ENV ABOT project (Assessment of water balances and optimisation based target setting across EU river basins). Detailed water balance models are developed across pilot River Basins (in IT, GR, DE and BG) using the WEAP model, where different future scenarios will run next to the baseline simulations, representing alternative futures. The development of the scenarios draws on the SCENES European narratives but downscales and “translates” the storylines into the specific regional conditions, to assess the robustness of the derived regional and sectoral targets (Kossida et al., 2011).

Figure 4.3 CIRCE Per unit change (A2-control) in mean annual runoff (left) and in water availability with unrestricted demand (right) for 2070-2100 with respect to control run (1960-1990) in the Mediterranean with DMI RCM



Source: Iglesias et. al., 2011.

4.4 Uncertainties related to scenario analysis

The analysis of scenarios provides us with information that facilitates target setting and the definition and subsequent implementation of policies. A number of studies have focussed on identifying mechanisms which help take advantage of scenarios and other futures-thinking in the policy making cycle. “BLOSSOM - Bridging long-term scenario and strategy analysis: organisation and methods” of the European Environment Agency points to the value of collaboration between the developers and users of scenarios and the need for methodological credibility to ensure uptake and assimilation of the information that is obtained (EEA, 2011).

Future water scarcity and drought scenarios need to take into account the uncertainties of the projections since any scenario analysis cannot be free of uncertainty. Uncertainty sources include possible error in the baseline assumptions and can relate to the use of different climate models - which even when fed with the same emissions scenario may provide very different results (Grubler and Nakicenovic, 2011, Pittock et al., 2001). Furthermore, they relate to bias introduced by the downscaling methods and techniques (Chen et al., 2011), to bias associated with the hydrological modelling and parameterisation, and the inherent uncertainty of the “forecasted response” that society is anticipated to have (Dessai and Hilme, 2007). Considering that water scarcity and drought have implications on numerous socio-economic sectors and ecosystems, as well as the cross-cutting nature of these phenomena, implies that any policy response can benefit when assessing its robustness and sensitivity against a range of possible futures. Despite uncertainties and the wide range of different approaches, state-of-the-art models and tools used to study and evaluate likely future water availability and water use have been proven robust enough as past predictions can now be validated in the recent trend analyses, and can at the minimum provide a realistic enough range of the best and worst-case developments. Efforts on improving scenario building and minimising the associated uncertainty should progress, strongly engaging though various stakeholders throughout the process of interpretation, development, and validation since the scenarios need to be tailored to the regional reality of Europe.

5 Adaptation Policies and Measures: current state and future needs

5.1 Overview: from WS&D evaluation to adaptation

Following the 2003 European drought event, and the drought in Spain and Portugal that crippled agricultural production in 2005, the first half of 2011 has proven to be one of the driest in a century in different parts of Europe (Fleig et al., 2005; Blenkinsop and Fowler, 2007; Carvajal, 2011). The European Commission recently determined that droughts in Europe have cost the economy 100 billion € over the last 30 years (EC, 2007a; EC, 2011). Major impacts of drought on agriculture tend to be among the first to be reported, yet the energy sector, both for hydropower and power-plants which require cooling water, is also affected by water scarcity and drought. Impacts on ecosystems, river navigation, public water supply and other sectors carry significant economic, as well as social and environmental, costs.

The 2010 European Council conclusions on water scarcity, drought and adaptation to climate change (European Council, 2010) recognised the eminent problem. Considering that the likelihood of this situation is increasing due to climate change, the European Council urged Member States to elaborate water scarcity and drought management plans (WSDMPs). Developing appropriate programmes of measures that facilitate adaptation to water scarcity and drought in Europe is challenging due to the diversity of economic, social, environmental conditions and wide range of situations where these are to be applied.

5.2 European policy context for water scarcity and drought mitigation

The European Commission's 2009 White Paper on Adapting to climate change thoroughly evaluates the urgent need for adaptation to the effects of climate change at an EU level across all sectors (EC, 2009a). It further discusses the nature of the adaptation policies and how these can be integrated into existing legislation and guidelines. The process is ongoing and the paper highlights the need to work closely with all Member States, stakeholders and international organisations to ensure that the proposed 2013 strategy is economically feasible, while still addressing the individual and collective adaptation requirements of all Member States.

In the area of water scarcity and drought, no distinct directive provides a management framework, but the European Commission Communication "Addressing the challenge of water scarcity and droughts in the European Union (EC, 2007a) is the primary policy document guiding EU Member States' efforts to combat water scarcity and drought.The Communication identifies seven policy options (pillars) for tackling water scarcity and drought issues:

- Water pricing
- More efficient water allocation
- Improving drought risk management
- Considering additional water supply infrastructures
- fostering water efficient technologies and practices
- Contribute to the development of a water-saving culture in Europe
- Improve knowledge and data collection

The assessment of the implementation of these policies is evaluated in periodic follow-up reports, the latest of which was published in 2011 evaluating the progress achieved in 2010 (EC, 2011). This report concluded that water scarcity and drought is not only a problem in Mediterranean countries but also in many other European countries. It largely showed continued progress with some stagnation:

- Most Member States have yet to implement national legislation in terms of water efficiency standards in buildings.
- Altogether 13 Member States have stated that significant activities with respect to leakage reduction have been instigated during the reporting period, including periodical maintenance works, updated guidelines, detection, leakage quantification and reduction measures.
- With regards to water efficiency in agriculture, the Commission and stakeholders have developed a handbook for administrations about integrating water issues into the Farm Advisory Services. In addition, it has been recognised that better control is required to identify and penalise non-authorised water abstractions which affect water availability.
- In 2010 pilot projects on halting desertification were launched, followed additional ones in 2011 more focused on the development of water asset accounts. These pilots provide examples of water efficiency measures and will contribute with examples and best practices to the WS&D policy review.

The EU water policy as formulated in the Water Framework Directive is based on the objective of achieving good status for all EU waters by 2015, which is to be understood both in chemical and ecological terms. The WFD is not directly designed to address quantitative water issues, although its goal includes mitigation of drought effects, and its environmental objectives include the adaption of a balance between abstraction and recharge of groundwater to secure the good quantitative status of the groundwater bodies. Furthermore, RBMPs can include more detailed programmes of measures, (PoMs) dealing with particular aspects of water management such as water scarcity and droughts (i.e. Drought Management Plans are proposed as supplementary PoMs). Currently, over 20 measures for managing WS&D are found in the RBMPs; the top 5 (Schmidt and Benítez, 2012) are as follows:

1. reduction/management of groundwater abstraction;
2. studies, research and pilot projects;
3. training, education and capacity building;
4. reduction of urban network losses;
5. development of drought management plans (DMPs).

At the Member State level, some countries, especially those faced with water scarcity and drought more frequently, have already implemented the preparation of drought management plans (DMPs) at river basin scale, such as Spain (Box 5.1), Cyprus, Greece (draft version currently under consultation together with the RBMPs). Ideally, these would be integrated in drought management at other scales such as regional, national and pan-European, an issue that can be addressed as the WFD comes under review. Numerous challenges are making the attainment of the WFD objectives difficult, and the EU response to the various prevailing issues has been elaborated in the recently published Communication “A Blueprint to Safeguard Europe's Water Resources”. The Blueprint aims to tackle the obstacles which hamper action to safeguard Europe's water resources. It is based on an evaluation of the existing policy, on a wealth of information and analysis (including the assessment of the Member States River Basin Management Plans – RBMPs), and on extensive public consultations, yet does not propose any one size fits all solution, in line with the principle of subsidiarity and recognizing that the aquatic environments differ greatly across the EU (EC, 2012b). The key themes addressed include: improving land use, addressing water pollution, increasing water efficiency and resilience, and improving governance by those involved in managing water resources. The main building blocks in relation to the WS&D policy review are, in addition to the improvement of water allocation based on ecological flow, water efficiency, adequate implementation of instruments and policies which provide incentives for water efficiency, water pricing with metering as a precondition, as well as cost-recovery (including environmental and resource costs) for water services taking into account the polluter pays principle and better planning (EC, 2012b). In the case of the latter, this is proposed through demand management, land use planning, the development of better information and indicators, policy integration and planning for emergency preparedness and response.

Cohesion Policy and its upcoming reform could provide mechanisms for mainstreaming water scarcity and drought considerations. Already, the implementation of water pricing schemes has been successfully implemented in some instances in Member States, while one of the Blueprint's proposed actions is to make water pricing/cost recovery an ex-ante condition under the Rural Development and Cohesion policy funds (EC, 2012b). National Adaptation Strategies (NAS) are another means of potential policy influence, especially as more countries proceed to preparing these. However, guidance is in many cases lacking, and the plans and policies being put forward are still relatively preliminary (http://www.eea.europa.eu/themes/climate/national-adaptation-strategies).

Box 5.1 Drought Management Plans in Spanish River Basins (Garrote et. al, 2007)

The Spanish drought management plans (DMPs) allow for planned drought management and are coordinated by River Basin Authorities. As their main achievement, they have avoided applying restrictions in urban areas throughout the recent drought periods. The plans establish drought phases, describe appropriate measures to apply according to homogenized national drought indicators, mitigate this extreme phenomenon's negative effects and foster a comprehensive follow-up of its episodes and evolution. They are powerful tools, which, through agreed bases among stakeholders, prioritise uses and protect water ecosystems under stressed situations.

The Tagus river plan, for example, was approved in 1998 and is constantly being reviewed and revised to accommodate climatic, institutional and social changes. Located at the heart of the Iberian peninsula, the Tagus river basin has a contributing area of 83,678 km^2 and is used for both agricultural and urban (including that of Madrid) purposes.

As with all good drought management plans, the use of multiple indicators is of great importance and in this case a wide variety are utilised to give the best warning of a period of impending drought. These range from assessing reservoir levels and using classical drought indices to uncharacteristic thickness of snowpack during winter. The threat level is then assessed and can be defined by 3 possible scenarios, each of which imply that different actions should be taken;

- Pre-alert scenario: The initial stages of drought have been detected but measures are restricted to low cost, voluntary actions such as information dissemination. This scenario is recognised when there is a 10% probability that full demand will not be met.
- Alert scenario: Drought is now occurring and action is defined by low to medium cost, non-structural measures which could include for example restriction on recreational water use. When there is a 30% probability that water deficits will occur, this scenario is realised.
- Emergency scenario: Impacts of the drought are now visible and supply is in danger. Infrastructure changes would be likely and urban supply may have to be sourced elsewhere. For an Emergency scenario to be declared there must be a 50% chance that there will be serious water shortages.

The definition of these thresholds is a highly problematic task and should be constantly kept under review given the importance of water to the numerous stakeholders and the public at large. The potential for conflict is thus greatly elevated and negotiations should be conducted where possible long before any period of drought occurs.

5.3 Adaptation Policies and Measures

5.3.1 Demand-side management for adaptation

Adapting demand to reduced water availability can be managed through a number of different strategies. In some regions, improving efficiency will be the main priority. There is a wide variety of measures and tools, relevant for each economic sector, spanning from technology improvements for water saving, leakage reduction, change of practices, to metering and controls, economic instruments, water reuse and awareness raising, all targeting in improving efficiency as presented in the EEA Report ‘Towards efficient use of water resources in Europe’ (EEA, 2012a).

The most likely improvements to be achieved will be related to infrastructure, where improvement and innovation of irrigation infrastructure will probably be a key area given the large share of demands for agriculture. Agricultural demands may also be decreased through the promotion of better crops with lower water requirements (Box 5.2). Yet, another likely strategy is the development of awareness and education campaigns to promote better water timing and more efficient agricultural practices in response to decreased availability of water.

Another important, and potentially controversial, area of demand-side adaptation is water pricing. Common economic policy instruments include charges for water usage, pollution taxes, tradable water withdrawal permits and fines. The idea behind water pricing strategies is to make water use as efficient as possible while ensuring water quality and ecosystems wellbeing. One of the main challenges for putting appropriate water pricing mechanisms in places is the existence of metering systems, particularly apparent in regions with greater water stress, which is in fact a precondition. In addition, it could be considered a costly and controversial issue given the social implications of such a measure. It has been observed that given water metering as an option, poorer families may try to economise on water usage thus compromising the family’s health. However, targeted metering is another viable option and tends to be more socially accepted. Efficient metering will allow accurate water pricing based on volume usage and may be useful for establishing a sector-by-sector approach to demand-side adaptation.

Many demand-side strategies have the potential to create conflicts between competing demands, by economic sector, geographical region, etc. However, in the face of decreased water availability navigating such potential conflicts is a necessary task. This means that society needs to become aware of the threats to water resources and also of the current state of water usage at the local level. Awareness campaigns focused on communicating risks and providing information to users are a key component of any demand-side strategy for adaptation.

Finally, in many situations, subsidies can lead to inefficient use of water or can create false incentives to increase water use. Removing environmentally harmful subsidies (EHS), notably in the agricultural sector but also in other sectors of the economy will ensure that water use can be reduced and will contribute to efficiency gains. Both the European Council and Parliament have called repeatedly for the identification and proposals on the removal of these subsidies and the Commission is expected to come forward with specific policy measures in the near future, also based on recent OECD work in this area.

Box 5.2 Adaptation to water scarcity and drought in the agricultural sector

In many European countries and particularly in the south, agricultural water use represents the highest abstraction of water in the country. The impacts of water scarcity and drought on this sector are felt not only at farm and regional level but, in the case of widespread or longer term droughts, can have international impacts on commodity prices and food security. It is therefore a priority to reduce the impacts of water scarcity and drought episodes on agriculture now and to prepare for potential increases in the frequency and intensity of these events. This is already occurring to some extent in Member States, and thus important advances will have to be made in the next few years.

Policies generally concentrate on research and development, education, introduction of more suited crops, efficiency improvements, among others. Agricultural adaptation options can be divided into autonomous adaptations (such as changes in varieties, sowing dates and fertilizer and pesticide use) and planned adaptations, referring to major structural changes such as land allocation, farming system and the development of new crop varieties (Bindi and Olesen, 2011; Moriondo, 2010). The most appropriate adaptation strategy is likely to be a combination of these and will depend on the impact to be experienced as well as the particular vulnerability of the system being considered. It is important to take into account the local conditions, including farm intensity, size and type, which are factors that have been found to play an important role in determining vulnerability to climate change in the agricultural sector (Reidsma et. al, 2010).

Although relatively simple and non-cost adaptation options may be easily implemented to tackle the expected change, others will have to be evaluated for cost, feasibility and impacts; in some cases, certain cultivations or agricultural activities may become unviable (Reidsma et al., 2010; Falloon and Betts, 2010; Moriondo et al., 2010; Bindi and Olesen, 2010).

When considering adaptation measures to address water scarcity and drought issues, demand-side management has a great potential. There are, however, numerous challenges, as previously mentioned, regarding possible future conflicts between water users, environmentally harmful subsidies, controlling illegal abstractions, designing and enforcing tight accountability, measuring and water licencing mechanisms (Box 5.3). These are gradually being discovered and addressed. In order for demand reduction adaptation to become a viable solution, cooperation is a key factor and requires appropriate institutional frameworks in order to secure that water users “play by the rules”. This does not only require enforcement; public participation and awareness are even greater priorities in order to ensure that the threats to water resources are understood and appreciated. This makes adaptation to less water a universal problem, which, if it is to be overcome, will require cooperation from all levels of society.

Box 5.3 Example of WSD management and mitigation action: The Catchment Abstraction Management Strategies (CAMS) in the UK (Dunbar et al., 2004)

The Environment Agency of England and Wales has developed Catchment Abstraction Management Strategies (CAMS) to improve the degree of consistency, transparency and clarity of process in the management of water resources (Environment Agency, 2010). Producing CAMS involves water resource assessments at the catchment and sub-catchment scale and uses these to establish a sustainable abstraction licensing strategy. As well as providing this information in an accessible format for businesses and the wider public, CAMS facilitates a more flexible approach to licensing through the granting of time-limited licences and licence trading. At the technical core of CAMS is the Resource Assessment and Management (RAM) framework (Environment Agency, 2001). The RAM Framework sets out the approach that the Environment Agency follows to determine catchment water resource status and allows the setting of sub-catchment scale environmental flows in a consistent and objective manner. It calculates a water balance for each sub-catchment and allocates the total available resource between the quantity of water that can be abstracted and that which must remain in the river (or aquifer) to maintain desired ecological conditions, called the in-river need. The Framework aims to integrate surface and groundwater resources, to reflect the varying sensitivity to the flow of different biota and habitats, protect both low flows and flow variability, and provide a mechanism towards achieving Good Ecological Status for the Water Framework Directive (WFD). Further, it aims are to produce an easily understood, structured and consistent method that explicitly includes uncertainty. The RAM Framework involves the following stages:

1. Definition of artificial influences and the benchmark (natural) river flow

At the outset of CAMs, assessment points (APs) on the river system are identified by knowledge of the catchment and abstraction issues. All further work is based around flows at the APs and WFD water bodies. Firstly, a naturalised flow duration curve is produced, either by a deterministic process of adding abstractions and subtracting discharges from a recorded flow time-series or by a regional steady-state model based on catchment characteristics (area, geology) and mean climate (Young et al., 2000). Water returned to the river (such as treated effluent) is an important feature of the RAM Framework, and is considered where data are available.

2. Definition of the abstraction sensitivity bands

For each AP, the environmental sensitivity to abstraction of the river basin is determined through consideration of three elements: 1. General characterisation/plants; 2. Fish; and 3. Macro-invertebrates. These are used to assign the water body to an Abstraction Sensitivity Band (ASB) of 1 low, 2 medium, 3 high, which sets the Environmental Flow Indicator (EFI) i.e. the environmental flow objective. The general characterisation classes are based on macrophyte survey data, but also indicate general physical water body types in the UK (Acreman et al., 2008). The fish element is defined from fish survey data together with a model that predicts fish communities in UK rivers (Cowx, 2001). For macro-invertebrates, a system called LIFE (Lotic invertebrate Index for Flow Evaluation (Extence et al., 1999) is employed, this relates flow to an invertebrate community score based on invertebrate samples compared with a target score derived using a statistical model (Wright et al., 2000).

3. Definition of the environmental flow

Once an AP has been assigned to a particular ASB, the overall Environmental Flow Indicator is produced in the form of a flow duration curve using a look-up table to determine permitted deviations from natural flow statistics, Qn30, 50, 70 and 95 to protect the ecologically relevant aspects of the flow regime. Deviations are presented as percentages of the flow at the different flow statistics points and these percentages vary according to the ASB to which the water body has been assigned. The basic procedures can define generic EFIs for any water body in England and Wales. Where additional local data exist, the EFI can be modified using local data and expert opinion if it is considered that this improves upon the generic procedures.

4. Classification of resource availability status

Various flow duration curve scenarios are compared with the EFI to assess resource availability. A key scenario is the recent actual level of abstractions from and returns of water to the river. Often the abstractor has not been using the full amount of licensed abstractions, so another important scenario is the full licence uptake. Where the scenario flow regime fails to reach the EFI, one of three levels of non-compliance are defined (1 to 3, with 3 representing the highest risk of ecological impact) according to the degree of departure. Hydroecological Validation (HEV) is then employed to 'ground truth' the compliance results. Time series of flows and LIFE scores are produced to check for observable patterns in flow and LIFE and to give an indication of the actual flow pressure that the river ecosystem may be experiencing. This then guides investigations for WFD and water company Asset Management Plan schemes, which can include remediation as part of the WFD Programme of Measures.

The end result is a classification of Resource Availability Status (RAS), where the four status possibilities are: Water Available, No Water Available, Over-licensed but not over-abstracted and, over-licensed and Over-abstracted.

In a catchment, the most critical (i.e. most stressed) AP will control the abstraction policy for upstream APs. This principle also extends to 'upstream' groundwater management units i.e. those that contribute base-flow to the river upstream of the AP. This means that a groundwater management unit that has a healthy water balance could nevertheless be managed so as to prevent deterioration of flows at the most critical AP. This reflects the dependence of river flows on groundwater derived base-flows and delivers a truly integrated approach to river-groundwater management.

5. Application

Figure 5.1 shows an example of resource assessment. The black flow duration curve line shows the natural flow at the AP, whereas the green line defines the EFI (environmental flow). The blue line shows a scenario, which in this example is the current flow regime where actual abstractions from and discharges to the river are included. The analysis summarizies whether and under what flow conditions new consumptive licences can be issued or if further investigation is needed to understand the extent to which the abstractions are causing an environmental impact. It can be seen that for flows greater than Q_{70} the scenario exceeds the EFI and additional water may be available for abstraction. However between at flows between Q_{70} and Q_{95} flows are less than the EFI. At this flow level, the scenario is defined as over-abstracted and represents a risk of failing Good Ecological Status for the WFD. HEV is then used to detect trends in low flows and ecological response. Figure 5.2 is an example from a different AP to that of Figure 5.1 showing a plot of flow time series and LIFE scores. Flows (the blue line) were lower overall in the period before 1990 and LIFE scores (red dots) are below the threshold line for flow stress (the dashed line) during this period. Post 1990 the flows are higher overall and more variable and LIFE scores tend to be above the threshold and appear more variable. In this example, measures were put in place after 1990 to ensure low flows were protected and LIFE scores suggest this has been successful.

Figure 5.1 Example of a CAMS assessment

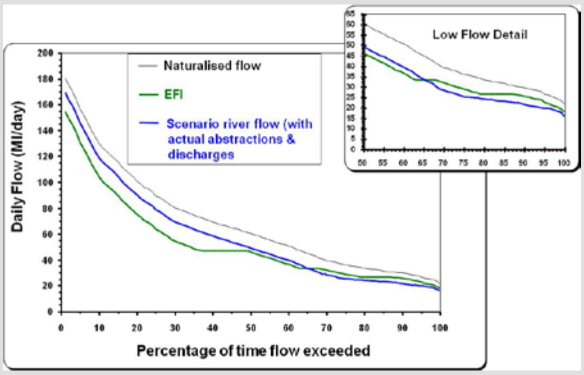
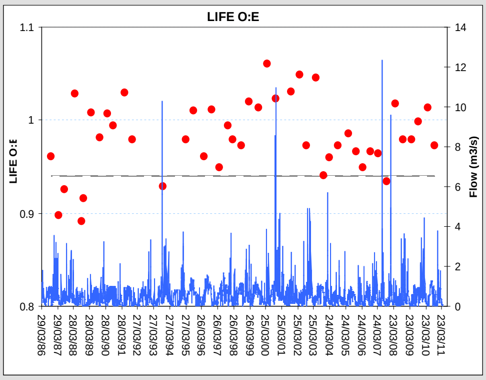


Figure 5.2 Example of a HEV plot



Source: Environment Agency (England and Wales)

The results of the resource assessment and HEV are fed into the Licensing Strategy phase of the CAMS process. This defines a water management strategy for the catchment, developed in consultation with stakeholders. Implementation then involves setting hands-off flow levels (flow levels at which abstraction should be reduced or stopped) and volumes for abstraction licences with the aim of maintaining the flow regime above or at the EFI. The EFI can subsequently be translated into seasonally varying Minimum Acceptable Flows should they be required. The procedure provides the first level classification. The impact of any specific abstraction licence can be examined in more detail, for example with habitat modelling.

5.3.2 Supply-side management for adaptation

Policies for dealing with and adapting to water scarcity and drought should concentrate on efficiency improvements and reducing demand as described in the previous section. However, in some circumstances, and if no further demand management is plausible, it may be necessary to balance demand side policies with the exploration of supply side measures. This is particularly true in arid regions and in those areas where water scarcity and drought are already causing considerable adverse impacts on certain sectors or for the population in general and where demand management alone cannot alleviate the problem.

In these cases, different options must be evaluated for their potential environmental, economic and social impacts. In some areas, desalination plants have been built in recent years or are being planned for the future. Particularly in coastal communities where water resources are often limited and groundwater is being affected by salt water intrusion and sea-level rise, this can offer a viable source of freshwater. Problems include the cost of the technology, running costs and energy consumption, and the generation of brine and resulting environmental problems of releasing it into the environment. Over recent decades, the cost of desalination plants has dropped considerably. This has facilitated the expansion of the installation or plans for desalination plants. More often in southern European countries, but also in some large urban centres such as London, desalination plants have been included in plans to adapt to growing water demand and reduced supply of water resources.

Other sources of water include considering alternative sources such as municipal wastewater, grey water and rainwater. This often requires investments in infrastructure and in some cases necessary information and campaigns to overcome public stigma. The treatment of municipal wastewater for reuse is growing in importance in different European settings. Technology can effectively ensure that all pollutants and pathogens are removed and that its use is safe. There is considerable growth potential as only few communities in Europe currently make use of this possibility (e.g. Canary Islands, Spain and Berlin, Germany).

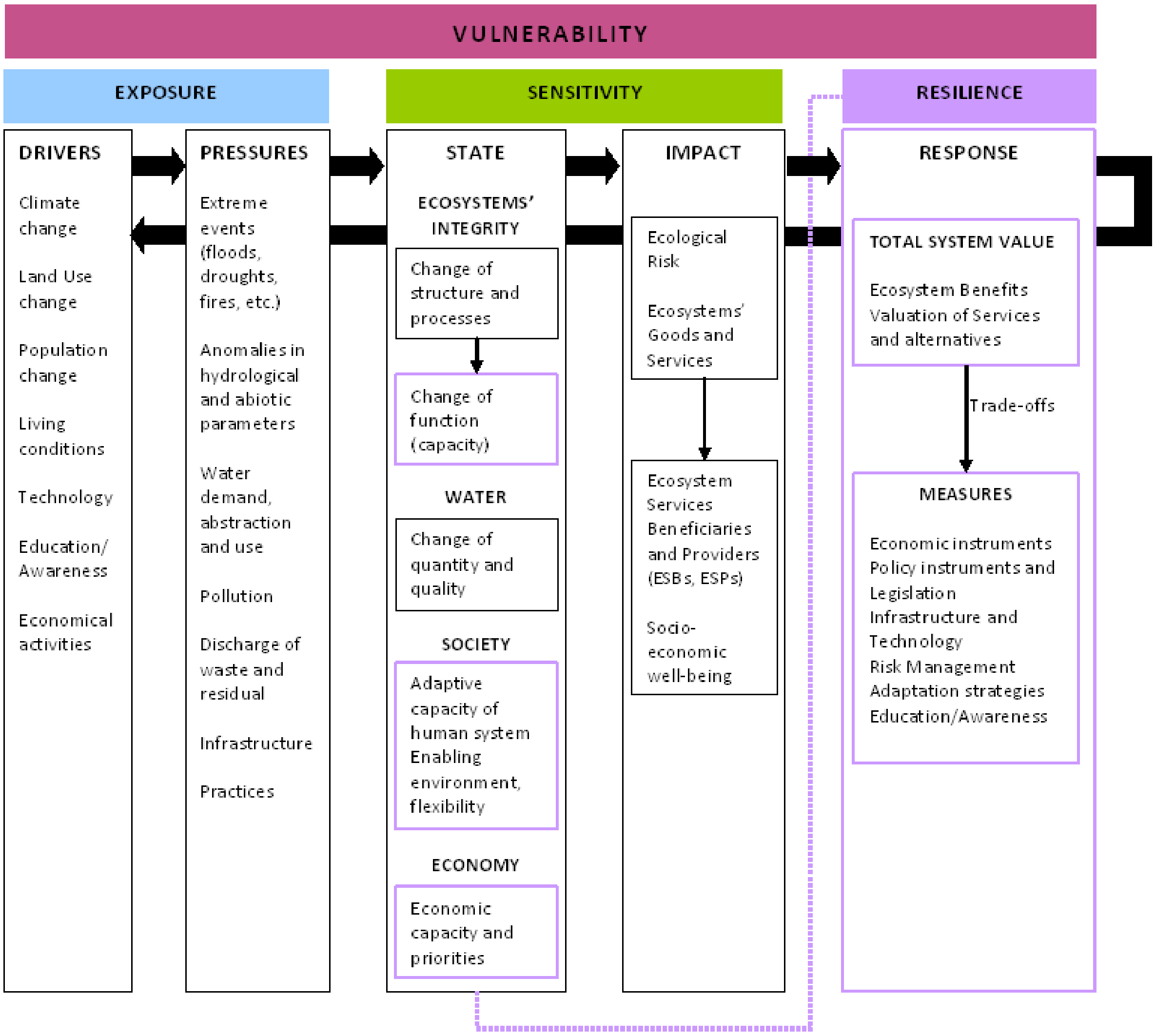
Supply side adaptation measures are already common practice in arid regions and other areas affected by water scarcity and drought and there is increased interest in extending these methods to other regions where the potential to harness waste, grey or rain water is high. The cost and information dissemination will likely be the greatest challenges faced by users wishing to implement desalination or water recycling programmes. Yet, it is clear that they shouldn't be a priority and that we should resort to them only under specific circumstances. As demand management alternatives fit better with climate adaptation, work with nature instead of against it, and provide a lot of space for innovation, they must be prioritised in managing and mitigating water scarcity and drought, while increase supply measures should only be brought in if the former cannot resolve the problems in hand.

5.4 Progress in the implementation of adaptation measures and future needs towards a risk management approach

Having realised the high economic, social and environmental cost of inaction regarding water scarcity and drought, and the likely worsening under climate change, the importance of identifying and implementing concrete adaptation actions has been recognised. Vulnerabilities will be most apparent in certain regions and sectors, most notably in the Mediterranean and in agriculture. Drought Management Plans continue to be implemented throughout Europe. Supply and demand side management for adaptation has demonstrated serious potential and international cooperation continues to improve, while there is plenty of room for innovation. The cost implications and the possible tensions surrounding water resources and the implementation of adaptation measures have been identified as stumbling blocks to rapid advancement. However, commitment and prioritisation by the European community is encouraging to future developments, and progress is made towards adopting a more integrated risk-oriented approach as opposed to a reactive crisis management approach.

A risk management approach entails the correct identification of the current and future risk, at the appropriate spatial and temporal resolution, defined as the combined effect of the hazard and vulnerability, the latest being associated with the exposure, sensitivity, and resilience of the physical and socio-economic system. The identification, prioritisation and quantification of all the components which constitute elements of the ecosystems' vulnerability to water scarcity and drought (Figure 5.3) is highly challenging as demonstrated in Chapter 3. While exposure relates to drivers and pressures, which are relatively more easy to quantify, the sensitivity of the system is linked to the current and potential future impacts on the ecosystems' goods and services, which, in turn, the beneficiaries and the providers of these services and the socio-economic well-being. The full identification, and especially the assessment of the sensitivity is thus very difficult and context specific. Finally, resilience needs to be considered in relation to a "total system value" where the adaptive measures applied are trade-offs of the ecosystems' benefits and value of services provided. Finding a representative methodology to analyse the cause-effect relations of all the above factors and their combined effect as the "total risk" is still weakly investigated. Nevertheless, efforts are made in this direction, both from the Member States level (*e.g. Greece elaborates on the production of drought risk and vulnerability maps in their DMPs – currently under consultation*), regional (*the DMCSEE is promoting a harmonised methodology for the production of drought vulnerability maps for the Southeastern EU countries, http://www.dmcsee.org/GISapp/*) and EU level (*the EG WSD is working towards the development of guidelines for drought risk mapping).*

Figure 5.3 Conceptual schema of the components of ecosystems' vulnerability to water scarcity from a risk-oriented approach



Source: created by the authors

It is widely recognised that comprehensive data are necessary to underpin such analysis at any level, and currently there is a lack of data and information, especially at the EU level, which would at least allow for raising awareness. In view of this problem, one of the actions set in the EC Communication on Water Scarcity and Drought in Europe (EC, 2007a), called for the development of tools for monitoring situations of water scarcity and drought. It distinguished between the European Drought Observatory (EDO, http://edo.jrc.ec.europa.eu/) to provide monitoring, early warning and forecasting (Vogt et al., 2011), the Water Information System for Europe (WISE, http://water.europa.eu/) to provide annual EU assessments of drought and water scarcity based on agreed indicators and data provided by Member States and stakeholders to the Commission or the European Environment Agency, and the exploitation of the Global Monitoring for Environment and Security (GMES, http://ec.europa.eu/enterprise/policies/space/gmes/index_en.htm) services for the delivery of space-based data and monitoring tools in support to water policies, land use, planning and improved irrigation practices (EC, 2007a). The recently published EC Communication “A Blueprint to Safeguard Europe's Water Resources” (EC, 2012b) includes a discussion on the right knowledge base for water resource management and promotes water accounts and detailed knowledge of water balances. In order to ensure that water is sustainably managed, water managers need to know the total amount of water that is available as well as the amount of water needed by the different users and by the environment itself. To this extent, for management purposes, but also for awareness purposes at the EU and regional level, there is a need for detailed and coherent information on the components of the water balance at the adequate temporal and spatial resolution. The EEA WISE-SoE#3 data flow on Water Quantity as well as the development of the water asset accounts can provide an ideal platform for the harmonisation and dissemination of this information and various related products (i.e. indicators, statistics, thematic maps) which can be easily communicated to the policy makers, stakeholders and the general public.

Early warning and forecasts are also vital in the case of risk management. Mapping of the development of droughts over Europe has been substantially progressed using a Combined Drought Indicator (based on SPI, soil moisture and fAPAR) developed by the EDO, with a further focus towards forecasting currently under investigation (Vogt, 2012). But in addition to preparedness regarding the development of the climatic conditions (i.e. drought) it is absolutely vital to have a clear view on the water balances and water consumption in the river basin, so as to be able to react early in scarcity situations.

Science plays a crucial role to underpin water policy formulation and implementation. A large number of research and demonstration projects, as well as concerted actions and initiatives, have been carried out in Europe over the past decade that have delivered a lot of information (guidance documents, reports, IT tools and data portals, methodologies, policy recommendations, etc.) helping to ensure drought preparedness and response. Many of the EU studies and projects consider the past, current and future impact of water scarcity and/or drought (environmental, human and socio-economic), as well as the development of management practices and other means to facilitate adaptation and reduce the impact of likely current and future drought and/or water scarcity events. A selection of EU projects focussing on water scarcity and drought is provided in Table 5.1.

Table 5.1 Overview of major European projects with research activities relevant to water scarcity and drought

Project	WS&D observations	WS&D future scenarios	WS&D impacts	WS&D adaptation and policy	Geo focus	Project website
AQUASTRESS	xx		xxx	xxx	Europe	http://www.aquastress.net/
ARID Cluster (WaterStrategyMan, Aquadapt, Medis)	xx	x	xx	xx	Mediterranean	http://arid.chemeng.ntua.gr/Project/
CapHaz-Net	xx		xx	xx	Europe	http://caphaz-net.org
CIRCE	xx	xx	xx	xx	Mediterranean	http://www.circeproject.eu/
CLICO			xx	xx	World	http://www.clico.org/
CECILIA		xxx			Central and Eastern Europe	http://www.cecilia-eu.org/
CLIMB		xx	x		Mediterranean, Middle East	http://www.climb-fp7.eu
ClimateCost			x		EU, China, India	http://www.climatecost.cc/
ClimWatAdapt	xx	xxx	x	xx	Europe	http://www.climwatadapt.eu/
DMCSEE	xxx		x	xx		http://www.dmcsee.org/ http://www.dmcsee.eu/index.php?option=com_content&view=article&id=21&Itemid=30
DROUGHT-R&SPI	xx		xxx	xxx	Europe	http://www.eu-drought.org/
DG ENV Preparatory Action on development of prevention activities to halt desertification in Europe. Halting desertification in Europe 2010 & 2011 Pilot projects: MIDMURES, DESIRAS, I-ADAPT, REDSIM, ABOT, HALT-JUCAR-DES, GuaSEEAW	xxx	x	xx	xx	Pilot RBs in Europe	MIDMURES (http://midmures.meteoromania.ro/) DESIRAS (http://www.ewp.eu/activities/desiras/) I-ADAPT(www.i-adapt.gr) REDSIM (http://www.redsim.net/) ABOT (www.abot.it) HALT-JUCAR-DES (http://www.evren.es/halt-jucar/index.php) GuaSEEAW
ENSEMBLES		xxx			Europe	http://www.ensembles-eu.org/
GLOWASIS	xxx				Europe, World	http://glowasis.eu
REFRESH		x			EU	http://www.refresh.ucl.ac.uk/
MEDDMAN	xxx		xx	xxx	EU	http://www.meddman.org/
MEDROPLAN	xx		xx	xxx	Mediterranean	http://www.iamz.ciheam.org/medroplan/
NEWATER			xx	xxx	Global case studies	http://www.newater.uni-osnabrueck.de/
Responses		x	x	xx	Europe	http://www.responsesproject.eu/
SCENES	xx	xxx	xxx	xxx	Europe & neighbours	http:// www.environment.fi/syke/scenes
WasserMed		xx			Mediterranean	http://www.wassermed.eu/
WATCH	x	xxx	x	x	Global	http://www.eu-watch.org/
Water2Adapt	x		x	xx	EU	http://www.feem-project.net/water2adapt/
Xerochore	xx	x	xx	xx	Europe	http://www.feem-project.net/xerochore/

Note: x-considered; xx-important issue; xxx-major focus

Few projects consider the full range from the observations of water scarcity and drought to adaptation and policy. The scales of application of these studies vary greatly from case specific, to regional, to national, to European and global, and thus it is inherently understood that the underlying methodologies, especially when we move further from the basic identification of the hazard to the characterisation of impacts, vulnerability and risk, differ. Yet, they provide a valuable input to policy, if their research results can be adequately capitalised by the policy makers. There is, in particular, a need for further in depth analyses of adaptation and policies at the European, regional, national and even local level. To this extent, science-policy interfacing is a crucial aspect that can help improving Europe's resilience to water scarcity and drought phenomena. A tight interaction between the policy makers, the stakeholders who draft the research agendas, and the researchers is important and beneficial for all parties, i.e. the research community can tune their focus on research priorities tailored to policy needs and real-life problems and thus of greater impact to the society, while the policy community has in their hands really applicable tools which can support decision making at various scales.

Although science-policy interfacing in this area is not currently as effective, important steps have been made towards reinforcing these links. Different initiatives exist trying to disseminate all relevant research knowledge and acquired products. The WISE-RTD Portal has been designed to disseminate water research outcome and experiences WISE-RTD Water Knowledge Portal, www.wise-rtd.info). Acting as a smart switchboard, WISE-RTD provides an easy access to customised selections of information available on the web. EMWIS (http://www.emwis.org/) is an initiative of the Euro-Mediterranean Partnership. It provides a strategic tool for exchanging information and knowledge in the water sector between and within the Euro Mediterranean partnership countries and is thereby another important tool in ensuring drought and water scarcity preparedness and response. The recently launched DG ENV Preparatory Action on development of prevention activities to halt desertification in Europe is reaching out to projects that focus on serving specific policy needs regarding e.g. the analysis of the implementation of the water accounts at EU level, the suggestions of concrete measures to improve water scarcity and drought mitigation, etc. The EEA, recognising the need to have detailed water balances at EU level has been engaged in the development of water accounts as a tool to support the analysis of water scarcity and possibly act as a guide on the further needs. The Expert Group on Water Scarcity and Drought has been working towards the harmonisation of definitions, the compilation guidelines for DMPs, the development of relevant indicators for WS&D, where technical experts were brought in when necessary to scientificly underpin work. The ERA-Net IWRM-NET has coordinated among the participating Member States a research agenda, also including water scarcity and drought as a priority, and has successfully funded several trans-national projects which research on issues relevant to the priorities set, so that the Member States can mutually benefit from their findings. Furthermore, on a similar concept, and recognising that "*Research efforts can be essential to address major societal challenges. In some cases these are so great that national research programmes cannot tackle them effectively on their own. Yet, the vast bulk of research programmes in Europe are run in an isolated way, leading to unwanted fragmentation or ineffectiveness" a Joint Programming* Initiative on Water (JPI - Water) has been recently initiated (http://ec.europa.eu/research/era/areas/programming/joint_programming_en.htm) trying to coordinate national research needs and remedy this situation. The Drought R&SPI FP7 project (Fostering European Drought Research and Science-Policy Interfacing) addresses the pressing need to improve drought preparedness through increased knowledge and an improved science-policy interfacing that will reduce vulnerability to future drought and risk in Europe. In the framework of the project a 1st Pan-European Drought Dialogue Forum has already been held in Cyprus this year (http://www.eu-drought.org/newsevents/10813457/The-1st-pan-European-Drought-Dialogue-Forum) with the objective to create an exchange platform among policy-makers, stakeholders and the scientific community on science-policy interactions.

Finally, DG Environment, in close cooperation with DG Research and Innovation and other DG's, has launched a proposal for a European Innovation Partnership on Water (EIP on Water, http://ec.europa.eu/environment/water/innovationpartnership/index_en.htm), endorsed by the EU Member States through Environment Council Conclusions on June 11th 2012, aiming to speed up innovations that contribute to solving societal challenges, enhance Europe's competitiveness and contribute to job creation and economic growth. The activities of the EIP on Water are structured around challenges in the areas of urban, rural and industrial water management, as well as addressing cross cutting themes, and evolve around identified priorities, water efficiency being currently one of them (drafting of the priorities is still in progress). Based on a multidisciplinary approach, identifying in which areas innovations are needed to develop solutions (research, technology, governance, ICT, financial or others), and ensuring maximum coordination between all stakeholders (policy-makers, SMEs and the industry, research communities, NGOs, etc.), the EIP on Water is a promising initiative to maximize science-policy interfacing and identify and overcome barriers to innovation, thus setting the scene for Europe to capitalize all available knowledge. As the EIP on Water plans to support Action Groups and Innovation Sites (to develop, test and demonstrate concrete activities, actions, prototypes and solutions in relation to particular water challenges) the water scarcity and drought thematic area can definitely benefit through participation in these activities.

Progress towards adopting risk-management approaches to combat drought and water scarcity is evident, and efforts to improve Europe's water resilience are ongoing. Yet, further developments are necessary to fortress our ecosystems, as well as the society, against these hazards, and if we want to successfully implement concrete and integrated solution researchers, policy-makers and practitioners need to convene in a think-tank to share information and experience, identify critical knowledge gaps, exchange best practices face-to-face for drought and water scarcity risk reduction and guide the future development based on real-life needs.

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