European Topic Centre
Inland, coastal, marine waters

Thematic Assessment on Vulnerability to Water Scarcity and Drought

Report for EEA

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Abbreviations used

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RCO: Rob Collins, EEA
BWE: Beate Werner
WVA: Wouter Vanneuville

1. Preface

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 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. The current draft of this report will be further elaborated to include reflection on future scenarios and adaptation and mitigation measures. As Annex to this report, a background document on the Water Exploitation Index (WEI), which is used as an indicator to assess water scarcity, and prevailing issues with the relevant data to underpin this indicator will be provided.

2. 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 economic impacts may be significant, affecting several sectors: agriculture, forestry, energy, 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 and the reduced annual water availability. 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[1], 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[2], while a fitness check of the action and new

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[1] European Commission, 2007. Communication from the Commission to the European Parliament and the Council: Addressing the challenge of water scarcity and droughts in the European Union. Brussels, 18.7.2007, COM(2007) 414 final, {SEC(2007)993}{SEC(2007)996}

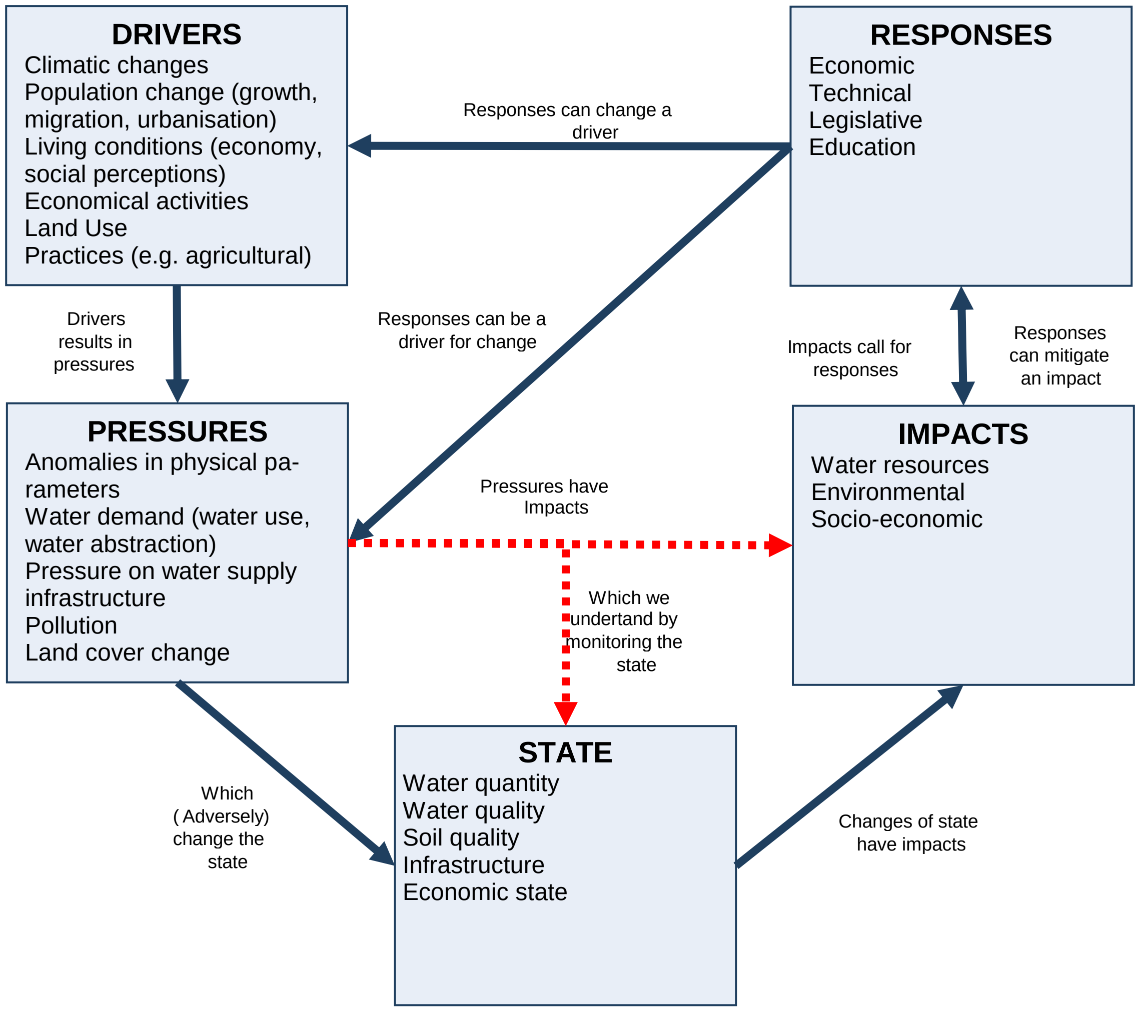
[2] European Commission, Water Scarcity & Droughts in the European Union http://ec.europa.eu/environment/water/quantity/eu_action.htm, accessed 15/11/2011

policy recommendations are expected in the 2012 Blueprint[3]. Clearly, responses and adaptation measures differ, depending on the issues and priorities of each region (i.e. demand management oriented vs. supply management). 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, reuse 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 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 2.1), 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 on 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 2.1 - Assessing WS&D under the DPSIR framework approach

[3] European Commission, A Blueprint to safeguard Europe's Waters http://ec.europa.eu/environment/water/blueprint/index_en.htm, ccessed 15/11/2011



Source: Kossida *et al.*, 2009[4].

3. Quantifying water stress across Europe

3.1. Drought and Water Scarcity occurrence in Europe (current and past conditions)

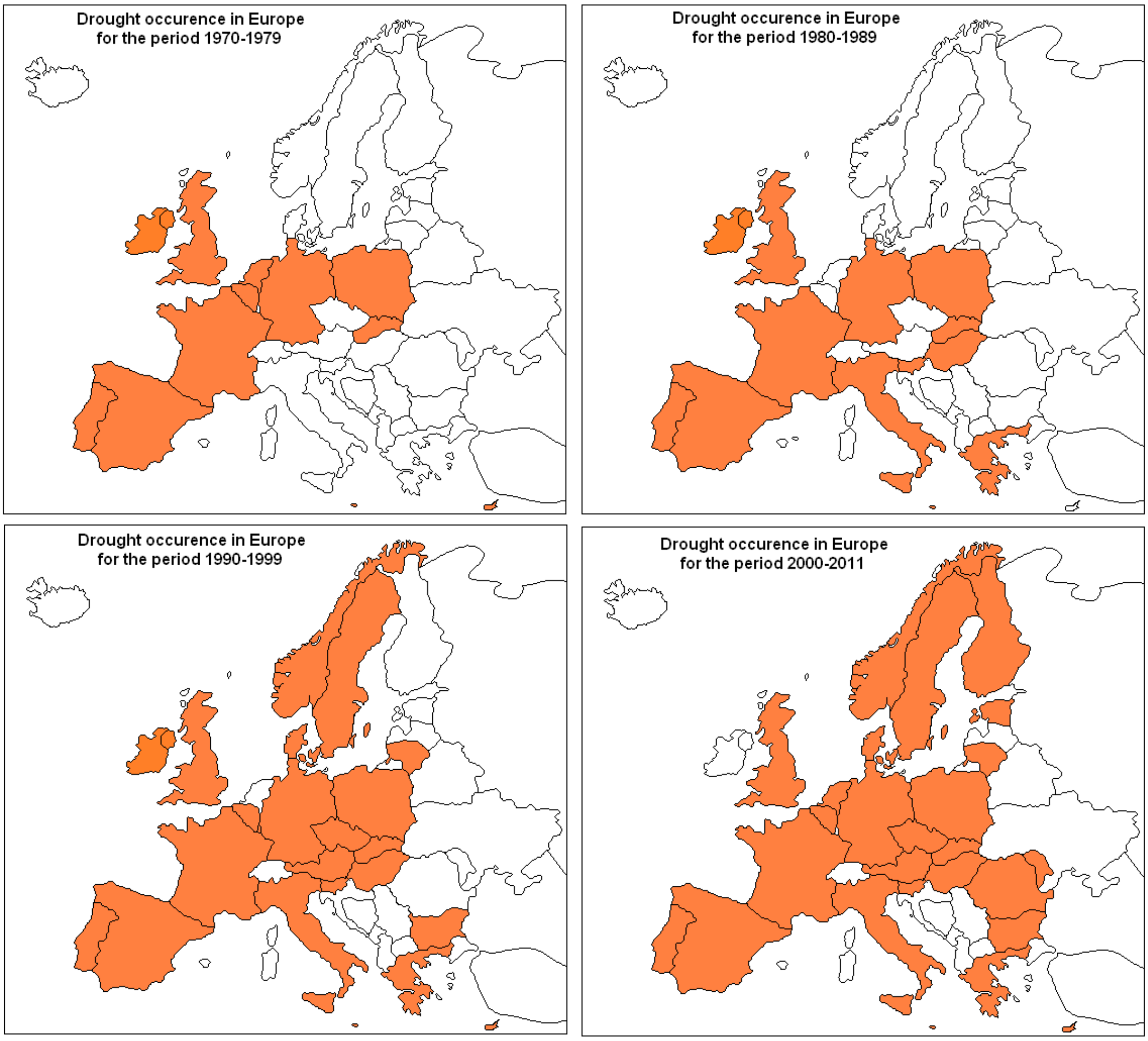
- Drought episodes in Europe

Many European countries have experienced drought episodes of various significance (ranging from less to more severe), duration (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. The following Map 3.1 illustrates the geographical extend of observed drought episodes in Europe

[4] Kossida, M., Koutiva, I., Makropoulos, C., Monokrousou K., Mimikou, M.; Fons-Esteve, J., Iglesias, A., 2009. *Water Scarcity and Drought: towards a European Water Scarcity and Drought Network (WSDN)*. European Topic Centre on Water (ETC/W) Internal Report, EEA, July 2009.

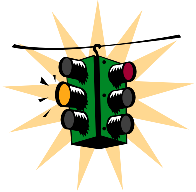
from 1970-2011. The background information has been collected from numerous sources (e.g. country reports, scientific papers, SoE assessments etc.) and was collated to produce maps per decade. It must be emphasized that these maps demonstrate drought episodes occurred in a country during the reference 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 12 in the period 1970-1979 to 26 in the period 2000-2011 (100% increase in geographical spread). A further comparison between the periods 1970-79 and 2000-11 per region (North, Central, Eastern, South EU) clearly shows that drought occurrence has significantly increased in the period 2000-11, not only in South and Central EU, but also reaching now North and Eastern EU (Figure 3.1). The year when most countries were affected (16 in total) was 2003, followed by 2006 (12 countries), and 2005, 1995, 1990, 1989 (11 countries). During 2011, in the period January to April, severe cumulated rain deficits were recorded in France (where the current year is the driest 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, 2011)[5]

Map 3.1 - Observed drought episodes in Europe from 1970-2011



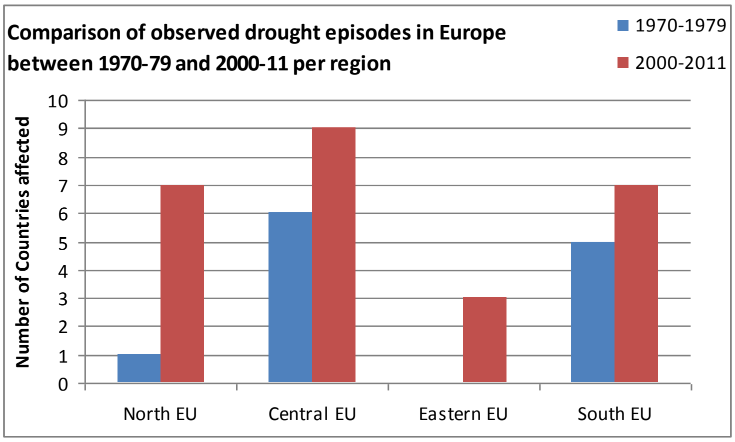
[5] Joint Research Centre (JRC), 2011. *Drought news in Europe: Situation in April 2011. Short Analysis from the European Drought Observatory (EDO).* JRC, available online: http://edo.jrc.ec.europa.eu/php/index.php?action=view&id=119, accessed 30/11/2011

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



Look Out!
Map 3.1 demonstrates drought episodes occurred in a country during the reference decade regardless of their temporal (few months or years) and spatial (local or nationwide) scale, and based on the best available information collected. Thus, the sub-maps clearly do not distinguish between severe or less severe events, or the frequency and extend of the events; they just simply present the countries where drought event(s) have occurred for general awareness purposes.
As this map is based on various compiled information, the EEA would like **feedback from the MSs** regarding the years that your country has experienced (in whole or in part) any drought episodes, in order to correctly update the sub-maps.

Figure 3.1 - Comparison of number of countries affected by drought episodes (per region) between 1970-1979 and 2000-2011

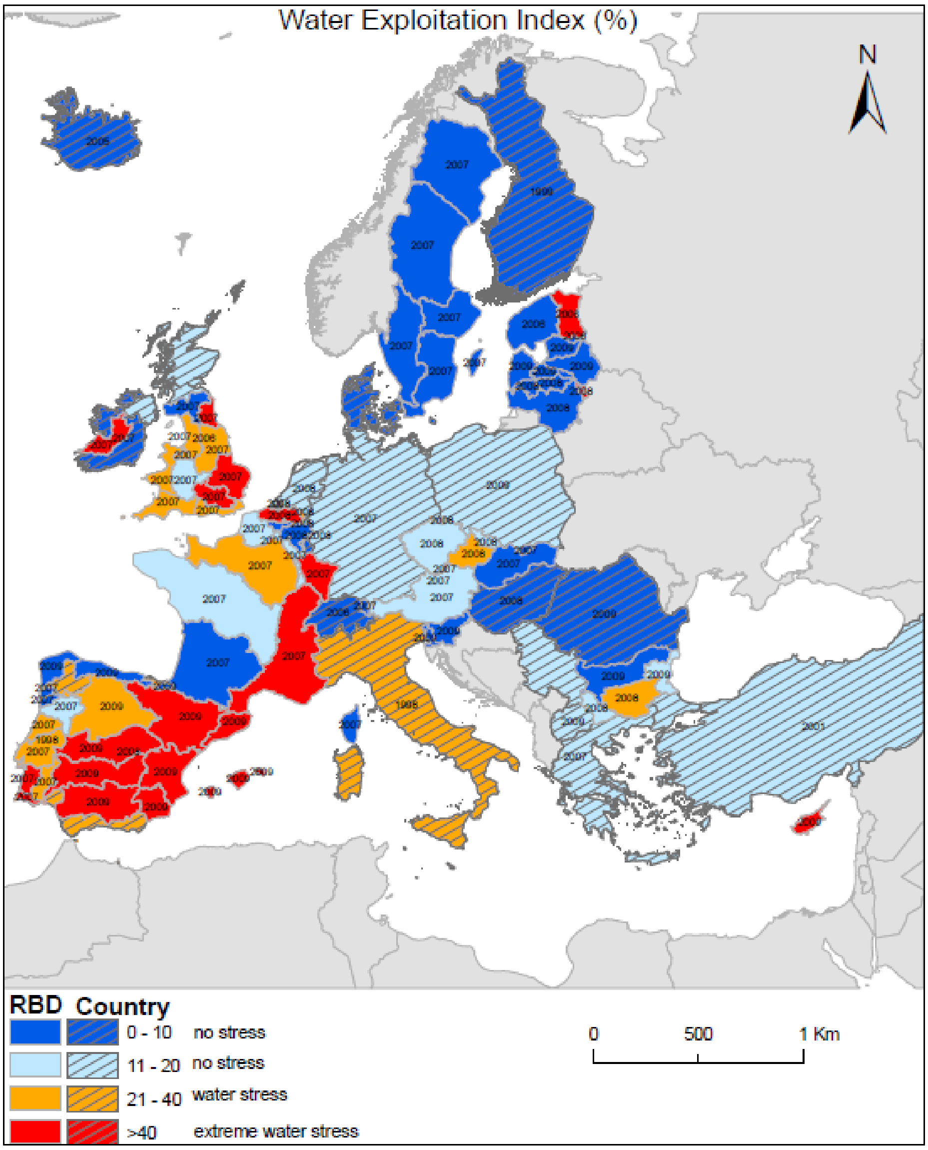


Source: Compiled by the authors based on multiple data sources (country reports, scientific papers, SoE assessments, etc.)
Notes: North EU: Denmark, Estonia, Finland, Latvia, Lithuania, Norway, Sweden, United Kingdom. Central EU: Austria, Belgium, Czech Republic, Germany, Hungary, Ireland, Luxembourg, Poland, Slovakia, Slovenia, Netherlands. Eastern EU: Bosnia & Herzegovina, Bulgaria, Croatia, Moldova, Romania. South EU: Cyprus, France, Greece, Italy, Malta, Portugal, Spain

- 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[1]. To assess the state of water availability vs. demand and identify water stress areas, indicators that capture the water balance are a useful simple tool. Based on the Water Exploitation Index WEI (defined as the ratio of annual abstraction over LTAA availability) 41 out of the 77 RBDs assessed (or 53%) are not water stressed (WEI<20%), while 14 (or 18%) are stressed (40%<WEI<20%) and 22 (or 29%) are severely stressed (WEI>40%) (Map 3.2). It is to be noted that besides the Mediterranean area, scarce RBDs exist also in Central and Northern Europe (UK Thames, Anglian, Northumbria, IE Shannon, BE Scheldt, AT Elbe, EE East Estonian and LT Daugava are severely stressed, while UK SouthEast, Humber, Dee, Northwest, Southwest, Western Wales, BE Meuse, BG Eastern Aegean Region and CZ Danube are stressed).Due to data limitations relevant proxies of the WEI have

been used in some cases, yet they do reflect at least occurrence of water scarcity episodes in these basins.

Map 3.2 - Water Exploitation Index WEI for European RBDs



Sources: compiled by the authors
Notes: Data come from multiple sources as follows:
Combination of WISE-SoE#3 and WFD: AT2000-Rhine, AT5000-Elbe, BG1000-Danube Region, BG2000-Black Sea Basin, BG3000-East Aegean, BG4000-West Aegean, SK30000-Vistula, SK40000-Danube
Combination of WISE-SoE#3 and websources: IEGBNISH-Shannon
Websources: ES014-Galician Coast, ES016-Cantabrian, ES020-Duero, ES030-Tagus, ES040-Guardiana, ES050-Guadalquivir, ES07-Segura, ES080-Jucar,ES091-Ebro, ES100-Internal Basins of Catalonia, ES110-Balearic Islands, ES120-Gran Canaria. web link: http://servicios2.marm.es/sia/visualizacion/lda/recursos/superficiales_escorrentia.jsp (*Total water resources in the natural system (hm3/year) Average value for the period between 1941-2009)
Reported to DG ENV for the Interim Report: PTRH3, PTRH4, PTRH5, PTRH6, PTRH7, PTRH8
WISE-SoE#3: all other RBDs
Eurostat JQ IWA: all Country level data

When assessing the state of water scarcity it is important to account for the actual water that is available for exploitation (vs. the theoretical). For example, some water may be practically unavailable due to specific geological and morphological conditions (i.e. deep aquifers). While this is very difficult to estimate, environmental and other legal water requirements (i.e. as defined by transnational treaties) need to be considered since they in fact limit the available water that can be actually exploited and used for consumptive purposes. Evidence exists that the 20-50% of the mean annual river flow in different basins needs to be allocated to freshwater-dependent ecosystems to maintain them in fair conditions. 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 presented in Table 3.1 below. 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. For example, assuming that cooling water used in AT-Elbe and BE-Scheldt RBDs is returned to the system, the respective WEIs would reduce to 21% and 37% respectively (from the 45% and 51% initial values). Finally, the temporal scale of analysis of WS conditions is extremely important, since the problem may not be apparent at an annual scale yet be acute at seasonal scale (Figure 3.2), especially during summer where the availability is usually lower and the demand picks up (Figure 3.3).

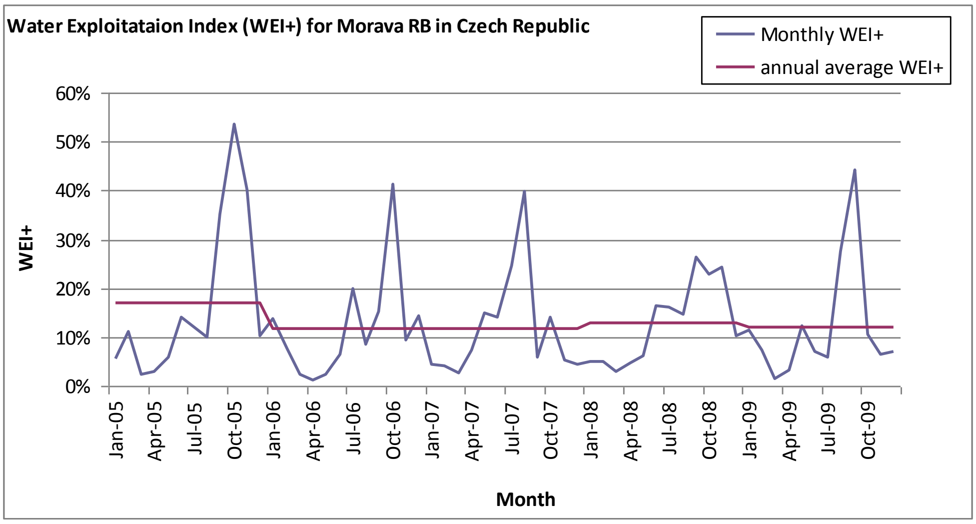
Table 3.1 - Environmental Water Requirements for different European basins and drainage regions

Basins or Drainage Regions	**EWR* (as % of available water)**
Danube	40%
Dnieper	34%
Elbe	45%
Iberia East Mediterranean	37%
Iberia West Atlantic	37%
Ireland	38%
Italy	30%
Loire Bordeaux	34%
Oder	47%
Rhine	44%
Rhone	40%
Seine	35%
Scandinavia	37%
*Environmental water requirements	

Source: Smakhtin et al., 2004[6]

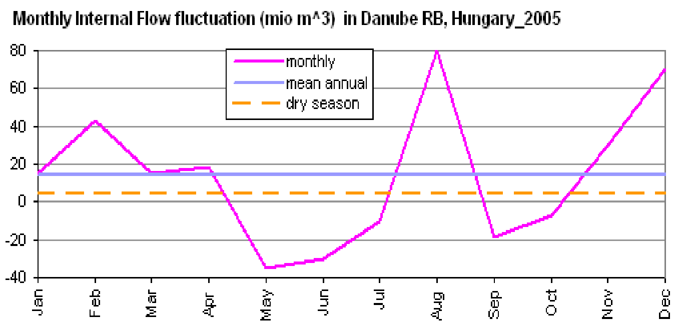
Figure 3.2 - Variability of the Water Exploitation Index (WEI+) at Morava RB in Czech Republic for the period 2005-2009 at monthly scale.

[6] Smakhtin, V., Revenga, C., Döll, P., 2004. *Pilot Global Assessment of Environmental Water Requirements and Scarcity*. IWRA, Water International, Volume 29, Number 3, Pages 307–317,

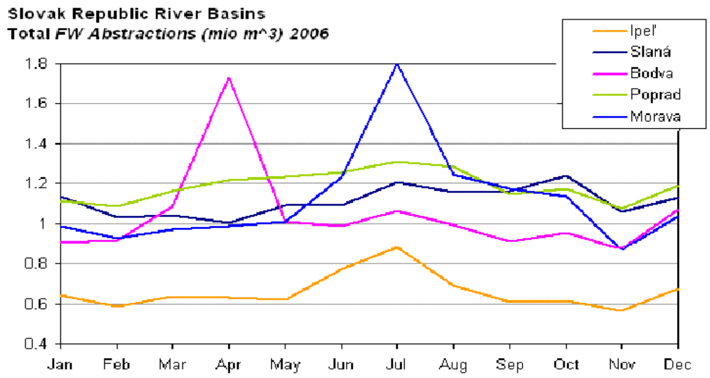


Source: EG WSD, provided by the representative of CZ
Notes: WEI+ has been corrected to further include water requirements (environmental and other) and returned water. The analytical expression is WEI+ = Abstraction / Water Availability – Water Requirements + Returned water

Figure 3.3 - Seasonal variability of water availability and abstractions in Hungary and Slovak Republic

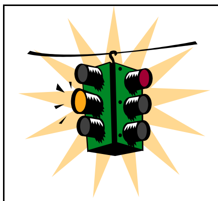


Monthly variability of water availability in Danube River Basin, Hungary for the year 2005



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

Source: WISE-SoE Test Data Exchange 2008, EEA



Look Out!

The Water Exploitation Index (WEI) is a valuable tool to formulate a harmonized message for awareness purposes on the state of the water resources, to provide an EU overview of water scarcity conditions, a hot spot analysis, and to be able to communicate the problem (to the best degree possible) to other EU policy areas (e.g. in inter service consultation with DG AGRI). Identifying the fact that the original WEI presented some limitations due to its simplified view of the water balance and its highly aggregated scale of implementation (i.e. country level), the EEA is working with the WFD CIS Expert Group on Water Scarcity & Drought (EG WSD) towards an improved formulation of this indicator (the so called WEI+) with the purpose of better capturing the balance between natural renewable water resources and abstraction, in order to assess the prevailing water stress conditions in a catchment. The proposed WEI+ aims mainly at redefining the actual potential water to be exploited (i.e. availability), since it incorporates returns and environmental requirements, tackling as well issues of temporal and spatial scaling.

	While improving the formulation of WEI+ is an important element, problems with the data that underpin this indicator are still evident. Due to unclarity or misinterpretation of definitions, random errors in reporting, differences in methodologies and calculation proxies, the data often do not reflect the relevant parameters, thus leading the readers in biased conclusions. EEA wants to highlight the issue of data incomparability and related uncertainty, and shed light into the underlying assumptions, proxies etc., so that miss-interpretation can be minimized. For this purpose a background document highlighting the different WEI representations which can result as products of using data from different source is compiled as Annex to this report. The EEA would like **feedback from the MSs** regarding the presented data and WEI options so to clarify uncertainties.

3.2. Main drivers and pressures

The driving forces of Water Scarcity are, as stated in the 2nd Interim Report[7] 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[8], De Marsily 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[9], De Marsily 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 EU from 1990-2011 is presented in Figure 3.4 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 2011 (current year) have been used to allow comparison of precipitation trends. It is interesting to observe that 2003 (the driest year in the 2000s) when compared with 1995 (one of the most dry 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. For the water resources, less precipitation and increased drought events translate directly to a pressure on water availability induced by climate change. Similar trends can be observed at regional scale, for example precipitation trends in Cyprus clearly present a decreasing trend, especially the precipitation of the wet season (Figure 3.5), with a LTAA (1971-2009) 200mm less than that of the previous period 1901-1970.

Figure 3.4 - Evolution of Drought in Europe based on the 6 months Standarized Precipitation Index (SPI-6)

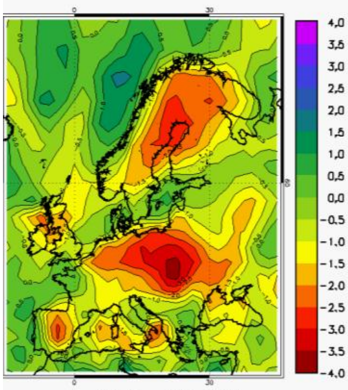
Fall	Winter	Spring	Summer

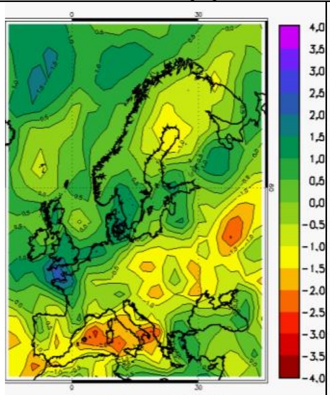
[7] DG Environment, European Commission, 2007. *Water Scarcity and Droughts in-depth assessment, 2nd Interim Report*. European Commission, June 2007.

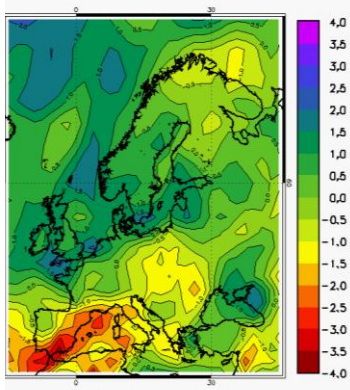
[8] French Academy of Sciences, 2006. *Continental Waters, Science and Technology Report #25*. Prepared for the French Government, coordinated by G. de Marsily. Published October 16, 2006 "EDP Sciences" Paris, 322 p.

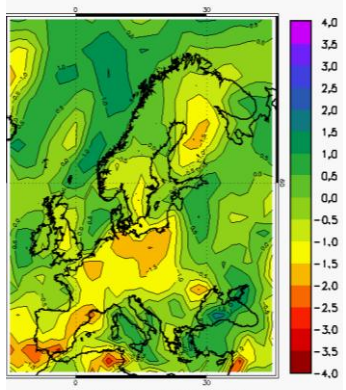
[9] De Marsily, G., 2007. Climate Change and its Links to the Water Scarcity and Drought Problems in Europe. Included in the publication of the Portuguese Presidency "Water Scarcity and Drought, A Priority of the Portuguese Presidency", Edition: Ministério do Ambiente, do Ordenamento do Território e do Desenvolvimento Regional, 2007.

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

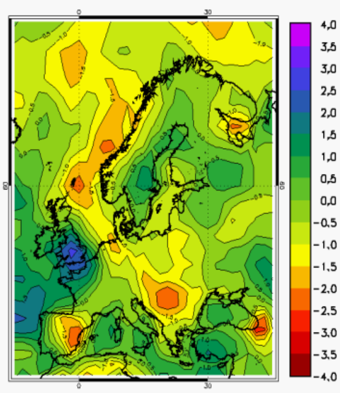

SPI 6 – OCT 1994

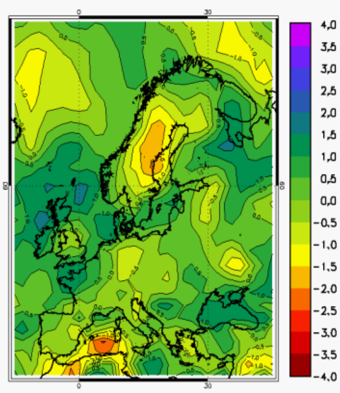

SPI 6 – FEB 1995

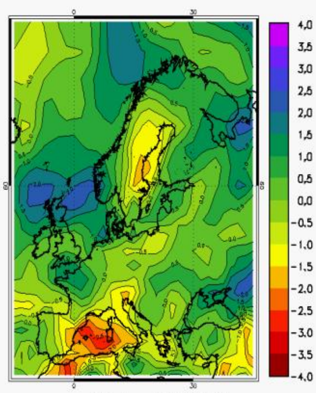

SPI 6 – MAY 1995

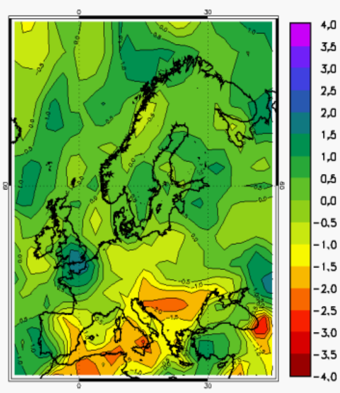

SPI 6 – AUG 1995

Hydrological Year 2000 (normal year)

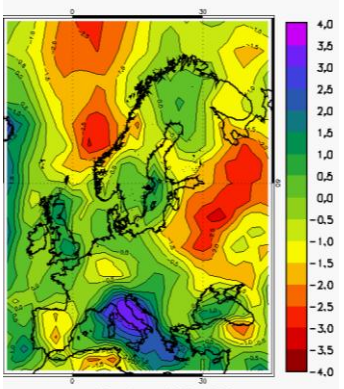

SPI 6 – OCT 2000

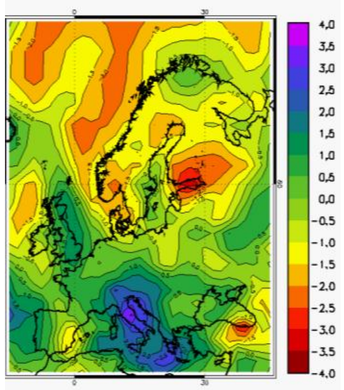

SPI 6 – FEB 2000

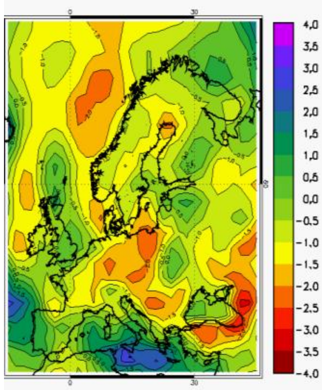

SPI 6 – MAY 2000

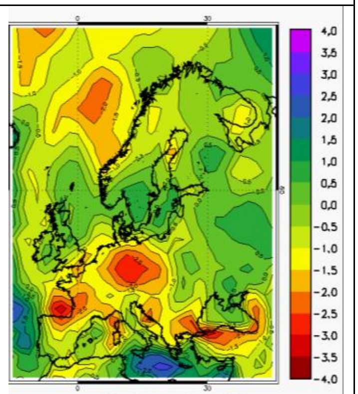

SPI 6 – AUG 2000

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

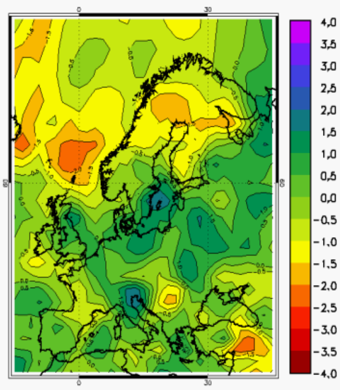

SPI 6 – OCT 2002

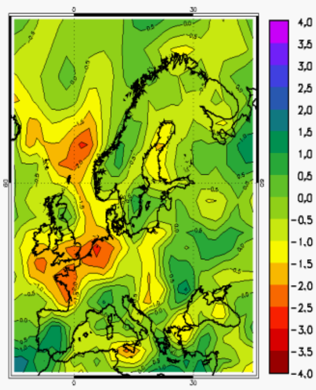

SPI 6 – FEB 2003


SPI 6 – MAY 2003


SPI 6 – AUG 2003

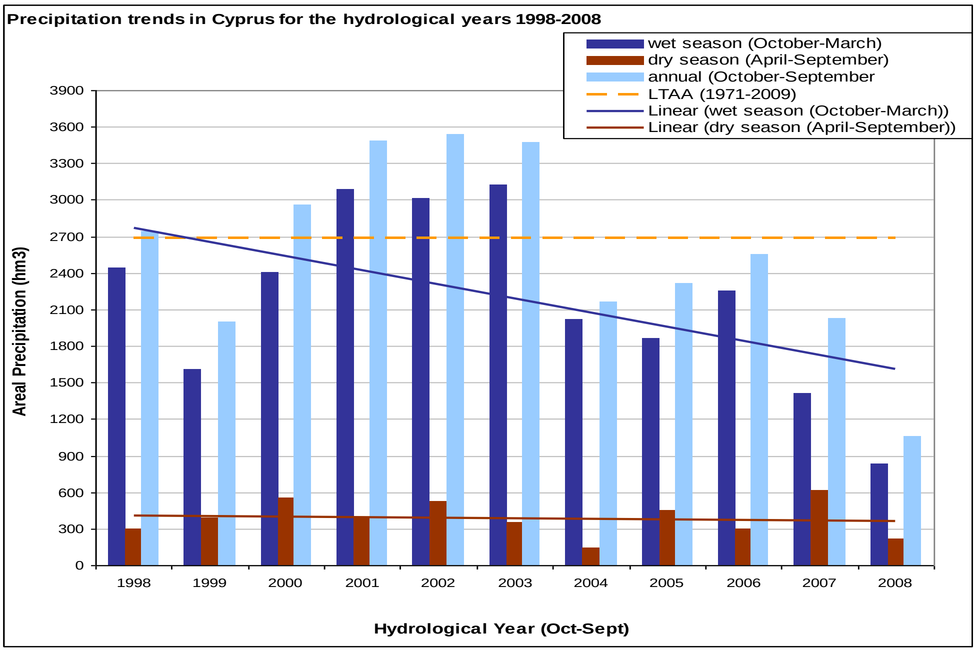
Hydrological Year 2011 (current year)


SPI 6 – FEB 2011


SPI 6 – MAY 2011

Source: APAT-MEDEA Drought Bulletin 2011, accessed July 2011 (http://www.isprambiente.gov.it/pre_meteo/siccitas/html/2011/index_2011.html)

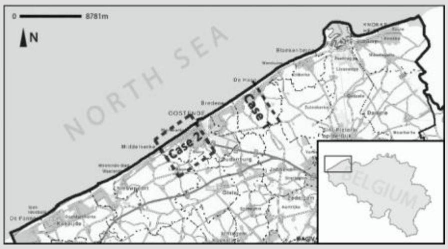
Figure 3.5 - Areal Precipitation (mio m³) trends in Cyprus for the hydrological years 1998-2008



Source: Kossida M., 2010[10]

Box 3.1: Saline intrusion in the Belgian coastal area

Figure 1 – Belgian Coastal area



From the end of the 19th C. onwards, the 65 km long Belgian coastal area endures an increasing pressure of tourism and urbanisation (Fig. 1). 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 temperature increase and sea level rising, the latter causing additional saline pressure and mounting of the freshwater layer. All 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, including simulations, and requires the monitoring of freshwater heads. These heads indicate the groundwater pressure by measuring the height of rise of the fresh water at a specific place and depth. Modelling simulations may provide in 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). Presently, the highest freshwater head values (being the highest height of rise values) are monitored below the dune areas. This is a result of rainwater infiltrating in these dunes, flowing towards the lower heads and directing towards the sea and the polders. The hydraulic freshwater head directing towards the sea will, with a rising sea level, be altered by increased salt water infiltration and partially replace the fresh groundwater reservoir. As a result of this opposite flow direction at the sea side, the dominant freshwater flow will shift towards the dunes. The result will be a reduced fresh groundwater availability in the dunes, therefore also limiting drinking water production. Compared to the current situation, salt water will be present within 150 years at a much smaller distance from one of the drinking water abstraction points than currently is the case (Figure 2).

[10] Kossida, M., 2010. *Towards a Water Scarcity & Drought Indicator System (WSDiS)*. Presentation to the WS&D Expert Group Meeting, Helsinki, September 30, 2010

Figure 3.6: **Vertical cross sections through the groundwater reservoir at De Haan for the year 2020 and 2160**. Freshwater heads (white lines and values) indicate the height of rise of the water level. The small blue top line in the polders is a small and vulnerable shallow fresh water layer.

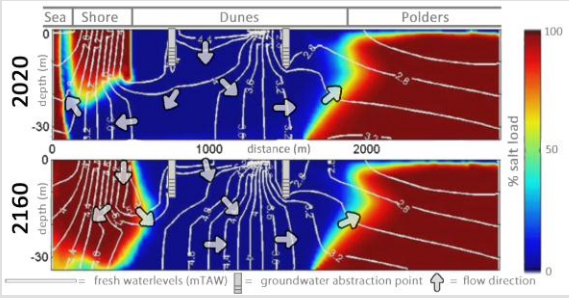
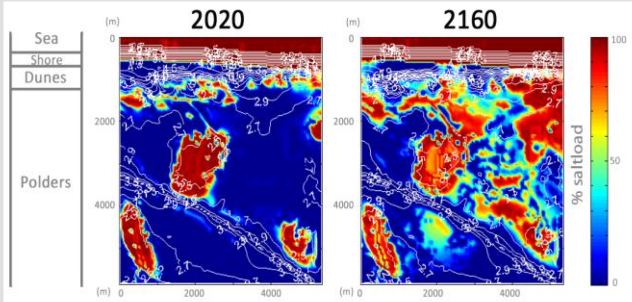


Figure 3.7: Horizontal cross section through the upper layer of the groundwater reservoir near Ostend for the year 2020 and 2160



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 3 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 pressure on the presence of this shallow fresh water. Models show an 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 freshwater table 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 of reused effluents of waste water treatment plants. 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 upstream salt water pressure and allowing instead the restoration of the more shallow fresh groundwater/superficial 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 impacts water demand either directly (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.) (MED WS&D WG, 2007[11]; Iglesias et al, 2007[12]). 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 D. et al., 200313). Map 3.3 presents those RBDs that identified the surface and groundwater abstractions as significant pressure in the WFD reporting, while Map 3.4 presents a classification of EU RBDs and Countries based on their total annual freshwater abstraction per capita, in

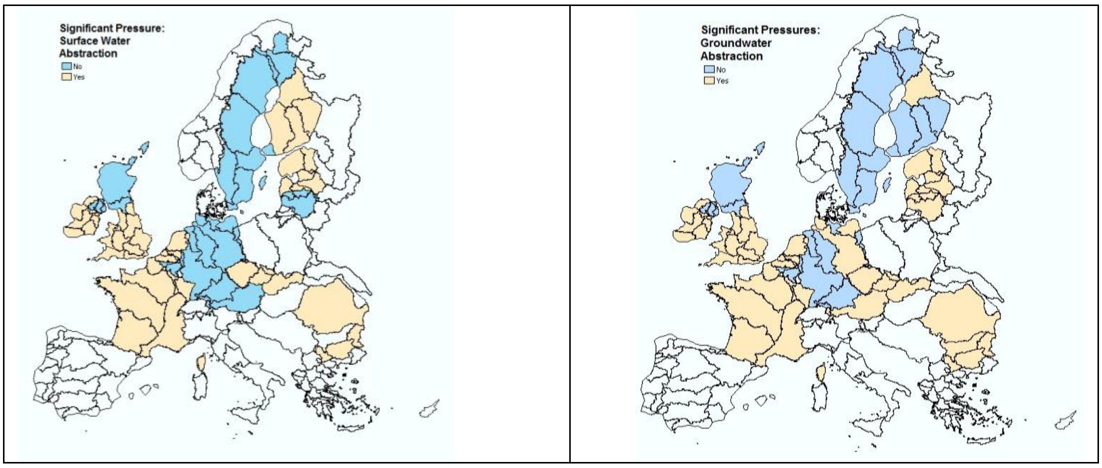
[11] Mediterranean Water Scarcity & Drought Working Group, 2007. *Mediterranean Water Scarcity and Drought Report*. Technical Report-009-2007, produced by the Mediterranean Water Scarcity & Drought Working Group (MED WS&D WG), April 2007.

[12] Iglesias A., Garrote, L., Flores, F., Moneo, M., 2007. *Challenges to Manage the Risk of Water Scarcity and Climate Change in the Mediterranean*. Water Resources Management (2007) 21:775–788, Springer.

[13] Borchardt D. and Richter S., 2003. I*dentification of significant pressures and impacts upon receiving waters.* Water Science and Technology, Vol 48, No 110, pp 33–38, © IWA Publishing 2003

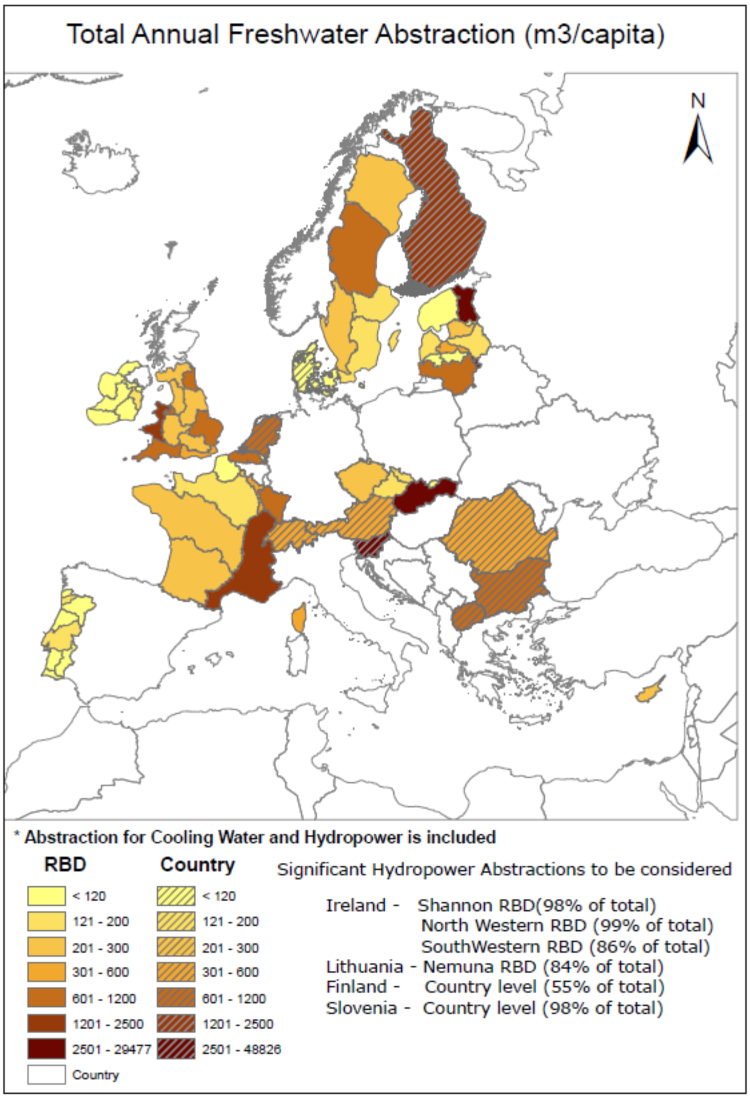
order to visualize the range of the volume of freshwater abstracted annually across Europe. It is to be noted that hydropower and cooling water abstractions have been included in the calculations. Thus, some RBDs appear with high withdrawals, and where the percentage of hydropower water use was known it has been explicitly marked in the footnotes of Map 3.4 (e.g. Nemuna RDB in Lithuania where hydropower accounts for 84%). Cooling water abstractions have not though been highlighted since they are considered as a consumptive use, it is nevertheless important to recognise that a vast percentage of this water is released back to the system as returned water.

Map 3.3 - RBDs that identified abstractions as significant pressure in the WFD reporting (left: surface water abstraction, right: groundwater abstraction)



Source: Eionet, CDR repository for each country, http://cdr.eionet.europa.eu/ , accessed April 2011

Map 3.4 - Total freshwater abstraction (m^3/capita) in European RBDs, grouped in seven classes.

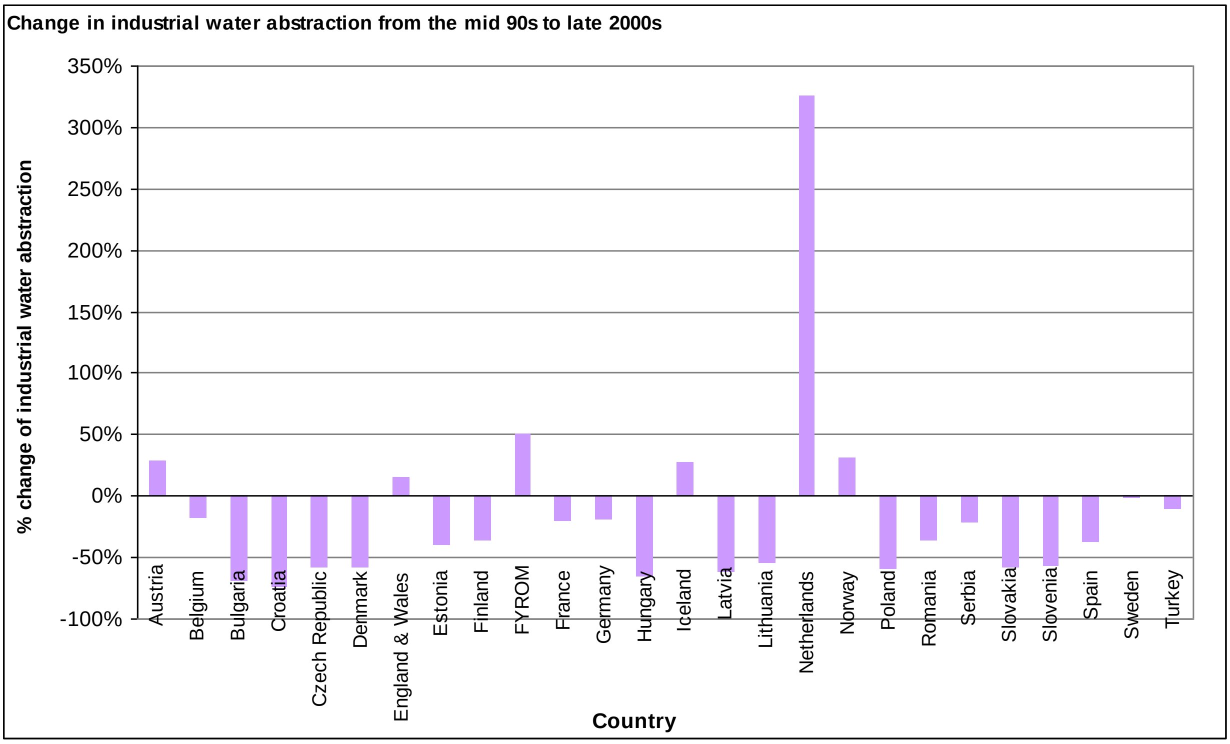


Source: Tekidou A. et al., 2011[14]

Note: The reference data in this map (total volume of freshwater abstraction) are collected through the WISE-SoE Water Quantity annual reporting of the MSs to the EEA, and include data reported until the year 2010 (the most recent year available from 2001 onwards is plotted).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.

Figure 3.8 - Percentage change of Industrial Water Abstraction per country: comparison of mid 90s to late 2000s.

[14] Tekidou, A., Kossida, M., Karavokiros, G., 2011. *WISE Map Specification [2011_TABS1]:Total Annual Freshwater Abstraction*. ETC/ICM Task 1.4.1.a-4 internal Report, EEA, November 7, 2011



Source: Eurostat (http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database)
Notes:
Mid 90s reference year:

1995	Austria, Belgium, Bulgaria, Czech Republic, Denmark, England and Wales, Finland, FYROM, Germany, Hungary, Iceland, Poland, Romania, Slovakia, Slovenia, Sweden, Turkey
1996	Croatia, Netherlands
1997	France, Latvia, Spain
1998	Estonia
1999	Norway
2001	Lithuania
2002	Serbia

Late 2000s reference years:

2009	Bulgaria, Croatia, Czech Republic, Denmark, Estonia, FYROM, Lithuania, Norway, Poland, Romania, Serbia, Slovenia
2008	Austria, England and Wales, Hungary Netherlands, Spain, Turkey
2007	Belgium, France, Germany, Latvia, Slovakia, Sweden
2005	Finland, Iceland

3.3. 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)[15]. 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

[15] Wilhite D.A., Svoboda M.D., Hayes M.J., 2007. *Understanding the complex impacts of drought: a key to enhancing drought mitigation and preparedness*. Water Resources Management, 21(5):763–774

grain crops, as well as livestock farming in **France** (USDA, 2011)[16]. At the end of May 2011, Credit Agricole, historically the farmers' bank, was announced by the French Minister of Agriculture to provide 700 Mio€ in loans to aid ranchers.

- **Navigation**: In the **Netherlands**, during dry periods, low river discharges cause 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[17] the long-term cost due to low water levels in the navigation sector is estimated at 70 Mio€, while the total annual cost of extremely low discharge conditions can increase up to 800 Mio€.

- **Energy**: During the severe heat wave in 2003, extremely high summer temperatures accompanied by significant annual precipitation deficits (IPCC, 2008)[18] 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)[19]. 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)[20]. 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)[21].

- **Groundwater degradation**: Groundwater overexploitation for over the last 40 years in the southern part of **Spain** has an enormous ecologic impact on the area (Ibáñez and Carola, 2010)[22], 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 com-

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[16] USDA Foreign Agricultural Service, 2011. *France facing most severe drought in 50 years.* USDA Gain Report Number: FR9069.

[17] Projectgroep Droogtestudie Nederland, RIZA, HKV, Arcadis, KIWA, Korbee en Hovelynck, Klopstra, D., Versteeg, R., Kroon, T., 2005. *Water shortages in the Netherlands: its nature, seriousness and scope (Summary)*. RIZA-rapport 2005.016; ISBN 9036957230. Ministerie van Verkeer en Waterstaat, Directoraat Generaal Water, Lelystad, NL, 120.

[18] IPCC, 2008. *Climate Change 2007: Impacts, Adaptation and Vulnerability*. Cambridge: Cambridge University Press.

[19] IAEA, 2004. *Operating Experience with Nuclear Power Stations in Member States in 2003*. International Atomic Energy Agency, Vienna.

[20] Müller, U., Greis, S., Rothstein, B., 2007. *Impacts on Water Temperatures of Selected German Rivers and on Electricity Produc� on of Thermal Power Plants due to Climate Change*. Forum DKKV/CEDIM: Disaster Reduc� on in Climate Change, Karlsruhe University.

[21] Förster, H., Lilliestam, J., 2010. *Modelling Thermoelectric Power Generation in View of Climate Change*. Regional Environmental Change, Vol. 11, No. 1, pp. 211-212.

[22] Ibáñez, C., Carola, N., 2010. *Impacts of Water Scarcity and Drought on Iberian Aquatic Ecosystems, Policy Note 04-0910*. Water Science and Policy Center.

munities causing disturbances in their behaviour and functions (Baptista et al., 2010)[23]. 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)[24]. 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 Boxes 3.2-3.4. 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 manufacturing industry is not reported to be widely affected.

Box 3.2: Economic Impacts (EIs) of Water Scarcity & Drought experienced by different European countries over the last years

Definition

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)

Country Specific Examples

– In **Slovenia** the direct economic cost of the 2003 drought (mainly loss of agricultural production and aid to farmers) reached 100 Mio€ (Sušnik and Kurnik, 2005)[25]. The total economic cost of drought in the years 2000-2006 was estimated at 247 Mio€ (86 Mio€ of national budget for recovery measures and 3 Mio€ for preparedness measures) (Gregorič, 2009)[26].

– Due to 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)[27]. Economic losses in agriculture and energy sector were estimated at 590 Mio€ and 300 Mio€ respectively in 2003, and at 250 Mio€ and 270 Mio€ in 2005[7]. During 2006-2007, losses of 144 Mio€ were reported in Savoia[7] skiing area in the Alps. During the 2009 summer heat wave, due to cooling

23 Baptista, J., Martinho, F., Dolbeth, M., Viegas, I, Cabral, H., Pardal, M., 2010. *Effects of Freshwater Flow on the Fish Assemblage of the Mondego Estuary (Portugal): Comparison between Drought and Non-Drought Years.* Marine and Freshwater Research, **61**(4), 490–501

24 Lupu, A., B., Ionescu, F., C., Borza, I., 2010. *The phenomenon of drought and its Effects within Romania*. Research Journal of Agricultural Science, 42 (4).

25 Sušnik, A., Kurnik, B., 2005. *Agricultural Drought Management: Status and Trends in Slovenia*. ICID 21st European Regional Conference 2005, Frankfurt (Oder) and Slubice.

26 Gregorič, G., 2009. *Impact of climate change on drought appearance in Slovenia and Southeastern Europe*. Environmental Agency of Slovenia .

27 Hightower, M., Pierce, S., 2008. *The energy challenge*. Nature 452: 285–286

water shortages the nuclear power generation industry in France, the biggest European electricity exporter, faced a shortage of about 8 GW resulting in import of electricity from Great Britain (Pagnamenta, 2009)[28].

– 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 productions) (WWF, 2006)[29]. 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 public water supply, industry, energy and agriculture were 9, 32, 261 and 519 Mio€[7].

– 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)[30]. In Finland losses of 10, 1, 50, 17 Mio€ were reported for public water supply, industry, energy and agriculture respectively[7].

– In the **United Kingdom** agriculture was the main economic sector affected by the drought event of spring 2011, with restrictions to 100 licenses of abstraction and warning of future restrictions to another 200 in parts of the East Anglia region (Environment Agency, 2011)[31].

– 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)[32]. As a result, the **German** Federal Hydrological Agency reported that ships on these rivers were forced to navigate at 20-50% of their capacity (Vindal, 2011)[33].

– 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 0.5t/ha respectively of a normal year) and energy sector (i.e. the sole nuclear reactor in Cernavoda on the Danube River was put out of function due to the low water level) (DMCSEE-JRC, 2009)[34].

The total annual and investment cost of basic and supplementary measures proposed by the Water Catchment Management Plan for the **Maltese Inland**[35] (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 Mio€ respectively.

Box 3.3: Environmental Impacts (EnIs) of Water Scarcity & Drought experienced by different European countries over the last 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)[36].

– In **Portugal** the 2004-2005 drought resulted in water level fall in many reservoirs (two major reservoirs, Funcho and Arade, completely dried out), reduced rives flows with a parallel degradation in their quality consequently affecting migrating species

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28 Pagnamenta, R. 2009. *France Imports UK Electricity as Plants Shut*. The Times, 3 July.

29 WWF, 2006. Drought in the Mediterranean: WWF Policy Proposals. A WWF Report, July.

30 Kuusisto, E., 2004. *Droughts in Finland – Past, Present, Future*. Hydrology Days.

31 Environment Agency, 2011. *Drought Management Briefing*, 16 June 2011, Environment Agency.

32 Van Loon A., 2011. *Presentation about the current drought situation in the Netherlands.* Hydrology and Quantitative Water Management Group, Wageningen University, 23 May.

33 Vindal, G., 2011. *Europe's dry spring could lead to power blackouts, governments warn*. Guardian, 31May.

34 DMCSEE-JRC, 2009. *Drought Monitoring in Romania*. 1st Joint DMCSEE-JRC Workshop on Drought Monitoring, Ljubljana, Slovenia, 21. – 25. September 2009.

35 MEPA, MRA, 2010. *Water Catchment Management Plan for theMaltese Islands, Final Draft*. Malta Environment and Planning Authority and Malta Resources Authority.

36 Sakalauskiene, G., Ignatavicius, G. 2003. *Research Note Effect of drought and fires on the quality of water in Lithuanian rivers*. Hydrology and Earth System Sciences, Volume 7, Issue 3, 2003, pp.423-427.

(e.g. lamprey in Minho river), water table decline in aquifers, salt water intrusion in transboundary waters bodies (e.g. Tagus Estuary), forest fires and removal of 220 tons of fish (MAOTDR, 2007)[37].

– The problem of salt water intrusion due to overexploitation is very common in several coastal aquifers of **Italy** (Antonellini et al., 2008)[38]. In 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)[39].

– In the **Maltese Island** 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, MRA, 2010)[35]

Box 3.4: Social Impacts (SIs) of Water Scarcity & Drought experienced by different European countries over the last 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 drought, the cost for public water supply was 23.2Mio€, 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 (MAOTDR, 2007)[37].

– 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 (WWF, 2006)[29].

– 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) [40].

– 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 (WWF, 2006)[29].

– During the spring drought of 2011 the **French** Ministry for Sustainable Development posed restrictions on water use in several French administrative departments. In August 2011 water use restrictions, that mainly affected irrigation and non-priority domestic uses (swimming pools, washing cars, etc), were applied at 67 departments out of 101 (Development Durable, 2011)[41].

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37 Ministério do Ambiente, do Ordenamento do Território e do Desenvolvimento Regional (MAOTDR), 2007. *Water Scarcity and Drought – A Priority of the Portuguese Presidency.* Ministério do Ambiente, do Ordenamento do Território e do Desenvolvimento Regional, Portugal.

38 Antonellini, M.. Mollema, P., Giambastiani, B., Bishop, K., Caruso, L., Minchio, A., Pellegrini, L., Sabia, M., Ulazzi, E. Gabbianelli, G., 2008. *Salt water intrusion in the coastal aquifer of the southern Po Plain, Italy.* Hydrogeology Journal (2008) 16: 1541–1556.

39 Czech Republic National SD Reports, 2008. *Drought Report*. CSD 16/17 (2008-2009), UN Department of Economic and Social Affairs, Division of Sustainable Development, National Information/National Report. Available online: http://www.un.org/esa/agenda21/natlinfo/countr/czech/drought.pdf , last accessed 15/11/2011

40 Collins, R., 2009. *Water scarcity and drought in the Mediterranean*. Change Magazine.

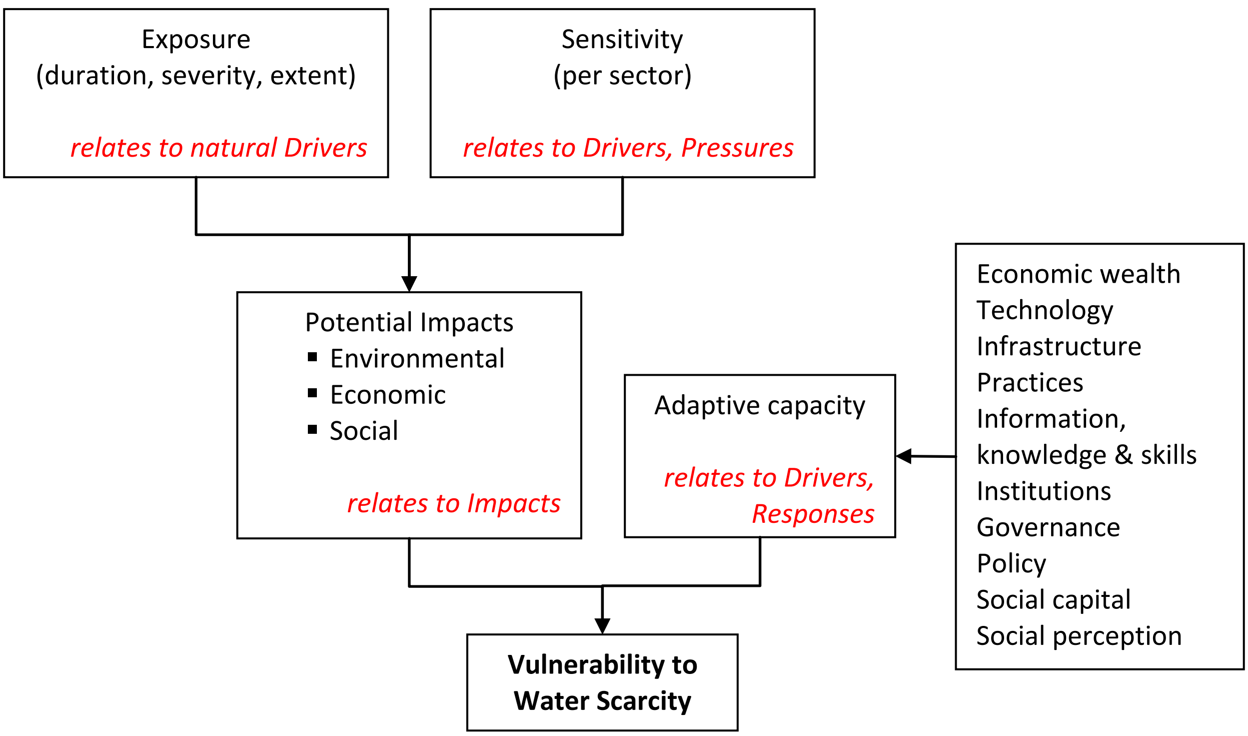
41 Development Durable, 2011. *Point situation sécheresse : limitation des usages de l'eau en vigueur au 21 juin 2011*.

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

4.1. 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 (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 4.1 presents a schematic of the key parameters that influence vulnerability to water scarcity and their interplay (adopted from IPCC Third Assessment Report "conceptualisation of vulnerability to climate change") linking them to the DPSIR framework.

Figure 4.1 - Conceptual schema of the components on water scarcity vulnerability



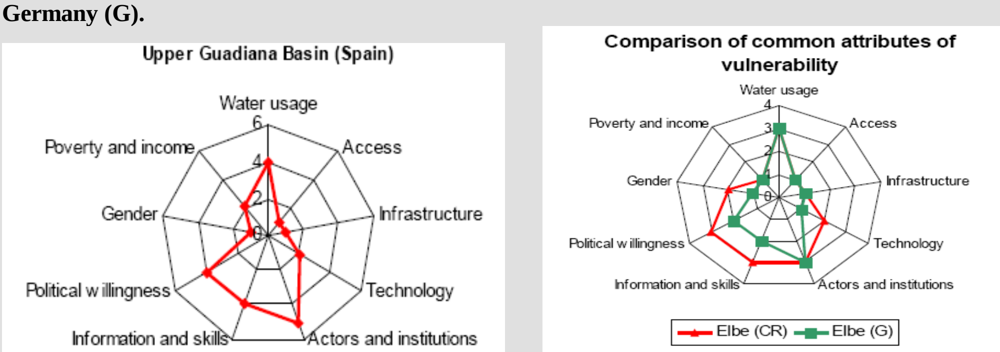
Box 4.1: Methodological approaches in defining Vulnerability to WS&D

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[42]. Furthermore, it emphasizes the significance of developing a formal framework which would ensure that representation of vulnerability is represented 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) 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 2)
- Attributes of vulnerability (water usage, access, infrastructure, technology, political willingness, institutions, income etc.)

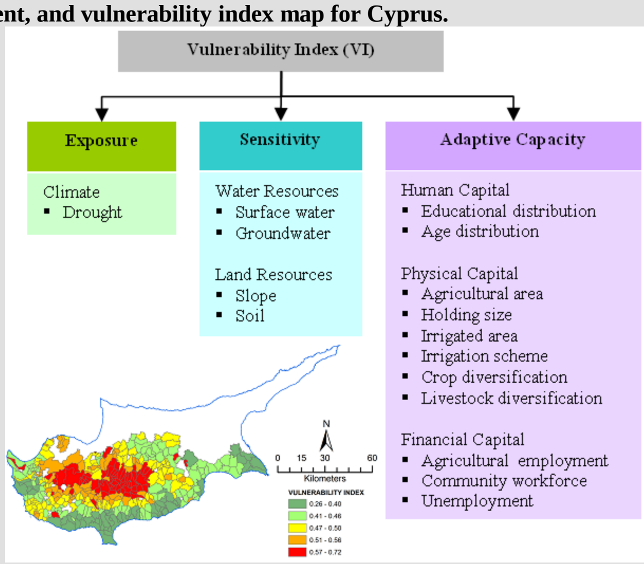
Figure 1 - Vulnerability profile for (a) the Upper Guadiana Basin (Spain), (b) the Elbe RB in Czech Republic (CR) and in Germany (G).



Using Weighted Vulnerability Indicators

In the framework of work package two for the European Commission project CLICO an approach regarding the vulnerability profile of rural communities to water scarcity and climate change is attempted (Deems, 2010)[43]. 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. 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 VI. This method was applied for Cyprus Republic, through a subdivision of 388 communities, and the indicator and sub-indicators used can be shown in Figure. In Figure is presented the final output of the research, the final map of vulnerability index for Cyprus.

Figure 2 - Indicators and sub-indicators for vulnerability assessment, and vulnerability index map for Cyprus.



42 Downing, T.E. and Bharwani, S. (2006). Baseline vulnerability assessment. Newater Report D2.1.1. Oxford: Stockholm Environment Institute.

43 Deems, H. J., 2010. *Vulnerability of rural communities in the Mediterranean region to climate change and water scarcity: The case of Cyprus*. Master in Environmental Management.

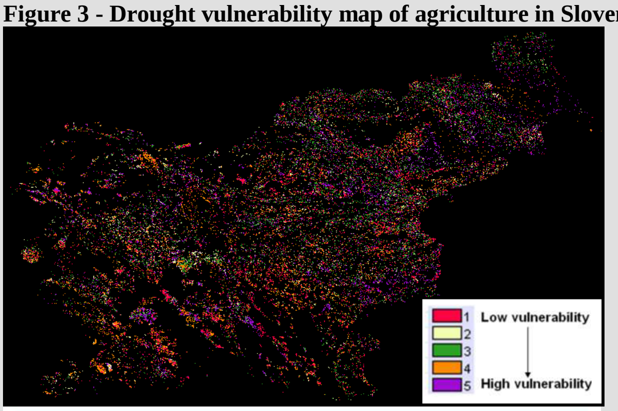
Another example of vulnerability assessment is provided by an approach in drought vulnerability of the agricultural sector in Slovenia (Slejko, 2008; 2010)[44,45]. More specifically, this research was part of the activities of the Drought Management Centre for Southeastern Europe (DMCSEE) and aimed at the development of a 'methodology towards drought vulnerability assessment and mapping for agriculture at a country level'.

For the implementation of this method weighted multi-criterial simulation was used. The different indicators were selected depending on data availability and reliability. These indicators were divided into three main categories:

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

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.

Figure 3 - Drought vulnerability map of agriculture in Slovenia



Distribution of Drought Vulnerability Classes

Vulnerability	Drought vulnerability class	Surface area [ha]	Percentage [%]
Very Low	1	79.271	29,0
↓	2	29.165	10,7
	3	57.904	21,2
	4	57.407	21,0
Very High	5	49.328	18,1
	TOTAL AREA	273.075	100

4.2. Selected case studies addressing WS&D vulnerability per sector

Different cases of vulnerability to water scarcity, for various European areas, are presented in this section with the purpose to highlight the diverse contributing factors as well as the strong influence of the prevailing regional conditions that can exacerbate or alleviate its magnitude.

4.2.1. Vulnerability of industrial sector to WSD - Poland and Bulgaria Case Study

The Przemsza River Catcment 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) (Aquastress, 2008)[46]. Over the decades, these anthropogenic activities have dramatically altered the quality and quantity of the region's surface and underground waters. As a result, the majority of its surface water bodies are in danger of not reaching a good ecological status by 2015 (Maciejewski et al, 2005)[47].

A full DPSIR analysis (Figure 4.2) and an overview of the stress generated by the local industries are demonstrated below (Table 4.1).

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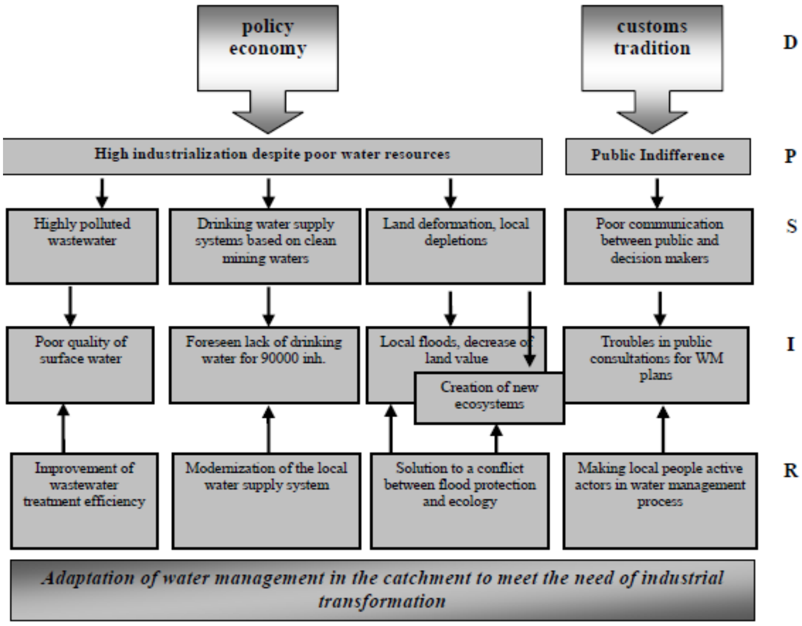
[44] Slejko, M., Gregorič, G., Bergant, K., 2008. *Drought vulnerability assessment for the agriculture: a case study for the west part of Slovenia*. Drought Management Centre for Southeastern Europe.

[45] Slejko, M., Gregorič, G., Bergant, K., Stanič, S., 2010. *Assessing and Mapping Drought Vulnerability in Agricultural Systems – A case Study for Slovenia*. 10th EMS / 8th ECAC Zürich, 13. September 2010.

[46] Aquastress Integrated Project, 2008. *Water saving in agriculture, industry and economic instruments*, *Part B-Industry*. Aquastress FP6 Integrated Project Deliverable.

[47] Maciejewski, M. et al., 2005. *Projekt raportu dla obszaru dorzecza Wisły z realizacji programu wdrażania postanowień Ramowej Dyrektywy Wodnej 2000/60/WE za rok 2004*. Draft report on the implementation of WFD 2000/60/WE in 2004 for the Wisła basin.

Figure 4.2 - DPSIR analysis for the Przemsza case study



Source: Aquastress, 2008

Table 4.1 - Stress generated by industrial users in Przemsza catchment

Water consumption and Wastewater treatment	**dm^3/ year**
Industrial water consumption	79.5
Groundwater abstraction	5.0
Surface water abstraction	21.7
Wastewater discharged (total)	263.8
Wastewater discharged directly to water or soil	261.5
Wastewater with substances very hazardous for water environment	13.6
Total Wastewater treated	237.7

The Aquastress research was focused on the area of the Biata Przemza basin, Przemsza's biggest tributary. In terms of quantity, a considerable variability of water resources was reported along the river. Lower depths of mining works result in the drainage of surface waters and lowering of groundwater table in some areas, while at the points where industrial and municipal wastewater is discharged water resources are increased. This increase is combined with deterioration in water quality due to large loads of pollutants carried by the discharges. Large ammounts of heavy metals (mainly lead and selenium), sulphates, coliforms and colour were the main problems that were detected in various tested spots.

It is evident that the industrial activities in the area have considerable impacts, and thus appropriate mitigation strategies need to be planned and implemented. This requires a series of actions but prerequisites a close cooperation with industrial plants to obtained details concerning water consumption, characteristics of industrial installations and production processes etc. Thus, the task becomes even more challenging, since obtaining the data for study purposes directly from industrial users of water, who are in conditions of competition, is far more difficult.

A **second** 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 4.2):

Table 4.2 - 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 n 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: Adapted from Aquastress, 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 Mio m^3/y (in clean and dirty cycles) and the freshwater consumption, which comes from 3 reservoirs, direct river and groundwater abstraction, amounts to 50-60 Mio m^3/y. The two main water-related stresses that the plant poses to the area is the excessive use of water and its polluted emissions. In order to identify the major bottlenecks of the industrial water use within the plant a water balancing method was adopted (Dimova G et al., 2007)[48]. Data collection took place between 2003 and 20006 and the main conclusions that came from the comparison of the results with the EC recommendations[49] can be summarized in Table 4.3 (identified per plant category in relation to their water use):

Table 4.3 - Problems related to the industrial water utilization in Kremikovtzi

No	Plant	n 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: Tarnacki et al., 2007

[48] Dimova, G., Tarnacki, K., Melin, T., Ribarova, I., Vamvakeridou-Lyroudia, L., Savov, N., & Wintgens, T., 2007. The water balance as a tool for improving the industrial water management in the metallurgical industry – Case study Kremikovtzi Ltd., Bulgaria. Proc. 6th IWA specialty conference on wastewater reclamation & reuse for sustainability, 9-12 October 2007.

[49] EC, 2001. European *Commission - Integrated Pollution Prevention and Control (IPPC).* Reference Document on Best Available Techniques on the Production of Iron and Steel.

Concluding, the Kremikovtzi plant is highly vulnerable to drought and water scarcity conditions due to the excessive utilization of water above normal demand levels and **mitigation through optimization of the industrial water use requires:**

(1) thorough understanding of the industrial process, reliable data and analysis of the potentials for water saving, emission reduction, water-energy efficiency increase;

(2) adequate monitoring and correlation of water quantity and quality issues for the proper and timely identification of threats and risks,

(3) close cooperation with the industrial water users, joining forces for pilot testing and on-site validation which can result in solid proposals.

4.2.2. Drought effect on rivers' water quality - Meuse River Case Study (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)[50]. According to the research carried out in the framework of the project 'Risk analysis of climate change' (Van Vliet and Zwolsman, 2008)[51] 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 an increased degradation of water quality in the river that would negatively affect its sustainability and ecological value. This would also cause water quantity issues, affecting important functions related to river flow and water temperature and quality. Such issues may possibly include 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 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)[51]: 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 reduced dissolution capacity.

4.2.3. Urban Vulnerability to WSD - 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

[50] Berger, H.E.J., 1992. *Flow forecasting for the river Meuse*. PhD Thesis, Delft University of Technology, The Netherlands.

51 Van Vliet, M.T.H., Zwolsman, J.J.G., 2008. Impact of summer droughts on the water quality of the Meuse River. Journal of Hydrology 2008, 353, 1– 17.

severe impacts of the drought as well as the mitigation measures taken (Martin-Ortega and Markandya, 2008)[52]. The drought period lasted about 20 months (from April 07 to January 2009) and the total losses are estimated at 1661 Mio€ (for a one-year period), almost 1% of the Catalonian GDP.

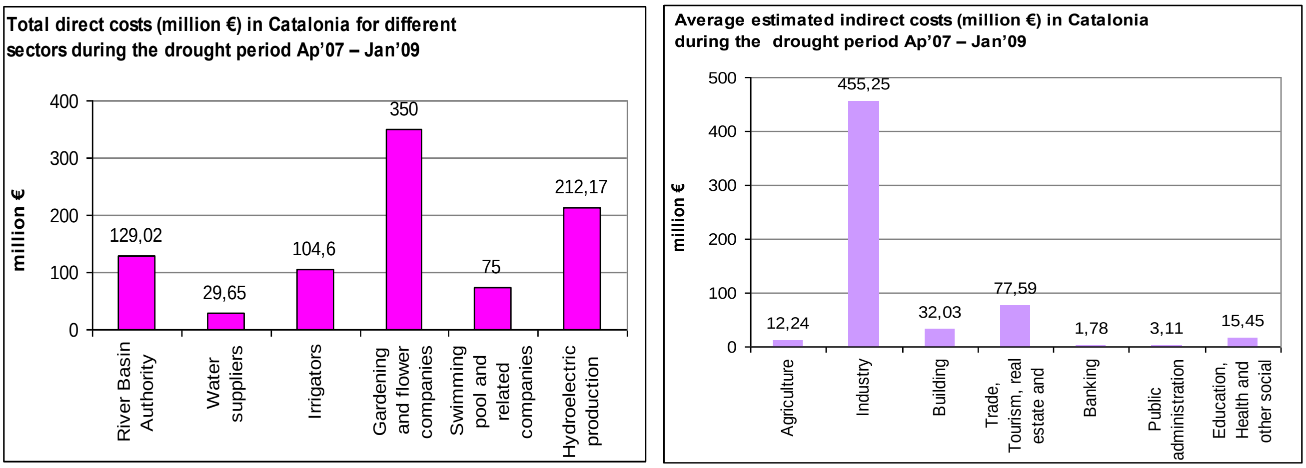
In Table 4.4 direct and indirect costs of the experienced drought of 2007-2008 are summarised as well as the cost of non market welfare losses is estimated. The first data come from an adaptation from Agència Catalana del'Aigua[53] (2009), while the non market welfare losses reflect a 'benefit transfer' approach from the Serpis River Basin (6th European Framework Project AquaMoney)[54] to the city of Barcelona.

Table 4.4 - 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: Martin-Ortega and Markandya, 2008

Figure 4.3 - Total direct costs in Mio€ (left) and average estimated indirect costs (right) in Catalonia for different sectors during the 2007-08 drought period



Source: Adapted from Agència Catalana del'Aigua, 2009

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52 Martin-Ortega, J., Markandya, A. 2009. *The costs of drought: the exceptional 2007 -2008 case of Barcelona*. Basque Centre for Climate Change

53 Agència Catalana del'Aigua, 2009. *Valoració dels costos econìmcs de la sequera a Catalunya 2007-2008*. Generalitat de Catalunya. Departament de Mediambient i Habitage.

54 AQUAMONEY: Development and Testing of Practical Guidelines for the Assessment of Environmental and Resources Costs and Benefits in the WFD. EU 6th Framework Programme. Contract # SSPI-022723. http://www.aquamoney.org.

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, 2008):
- Emergency measures: 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, e.t.c.) as well as supply measures that were not related to water distribution (i.e. water shipping).
- Structural measures: 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.
- Additional structural measures: These are measures for the long-term conservation of water supply (i.e. re-opening of not-in-use wells and grilling of new ones, set up of water treatment plants).

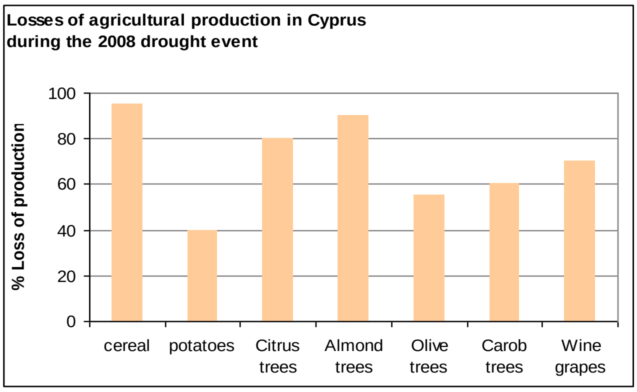
Concluding, Catalonia and especially the city of Barcelona in Spain were highly vulnerable to the 2007-08 drought event, with numerous sectors experiencing adverse impacts and the total direct and indirect costs summing up to about 1,400 Mio €. **Measures to both decrease/control demand and increase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

4.2.4. Isolated Island Case Study - Cyprus Case Study

As most of the 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[55] (2010) it is estimated that since 1970 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 cubic meters, 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, Cyprus is classified among the countries of high water pressure, even though great expenditure has been invested in water infrastructure, particularly modern irrigation systems, dams, of a total capacity of 326 million €, 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 sector (Figure 4.4) and domestic water uses, the island's water resources ended up extremely over-exploited (major dams such as Kouris, Yermasoyia and Dipotamos Dams dried out, groundwater was reduced by 40% and aquifer salinization was detected) (Pouros, 2008)[56]. As an emergency measure to balance water shortage, 8 Mio m^3 were imported by Greece. Total assistance provided to the farmers was estimated at 67.50 Mio €, while the total cost for short-term emergen-

Figure 4.4 - Losses of agricultural production during drought 2008 in Cyprus



Source: Pouros, 2008

[55] MANRE, 2010. *Cyprus Revised National Strategy for Sustainable Development (in Greek)*. Ministry of Agriculture, Natural Resources and Environment, Department of Environment.

[56] Pouros, P., 2008. *Addressing the Challenge of Drought and Water Scarcity in Cyprus*. Presentation by the Permanent Secretary of the Ministry of Agriculture, Natural Resources and Environment

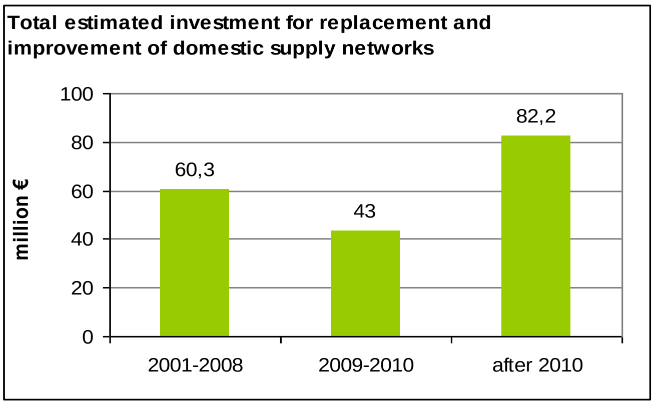
cy measures (actions to be taken in 2009 and 2010) to enhance domestic water supply was estimated at 287 million €. Finally, restrictions of water supply for both agriculture and domestic use were applied, limiting the supply to households to only 36 hours per week.

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[57]; EU Maritime Affairs[58]):

<u>Infrastructure</u>

- Installed desalination capacity at 112 m^3/d in 2008. Total capacity of all desalination plants in Cyprus is planned to reach 96 Mm^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

Figure 4.5 - Investments for replacement and improvement of domestic supply networks from 2001-2010 in Cyprus



Source: Adapted from EU Marritime Affairs

<u>Economic instruments</u>

- Subsidies to water consumers for improvement and leakage minimizing of water supply networks (**Error! Reference source not found.**)
- Water pricing

<u>Educational measures</u>

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

<u>Legislative and Policy Measures</u>

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

Concluding, **in 2008 Cyprus has been 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**.

4.2.5. Climate change scenarios on WSD vulnerability of agriculture - Czech Republic Case Study

Even though the country of Czech Republic is not using high amounts of water in agriculture at the moment according to the 2008 Report on Water Management in the Czech Republic[59] this situation

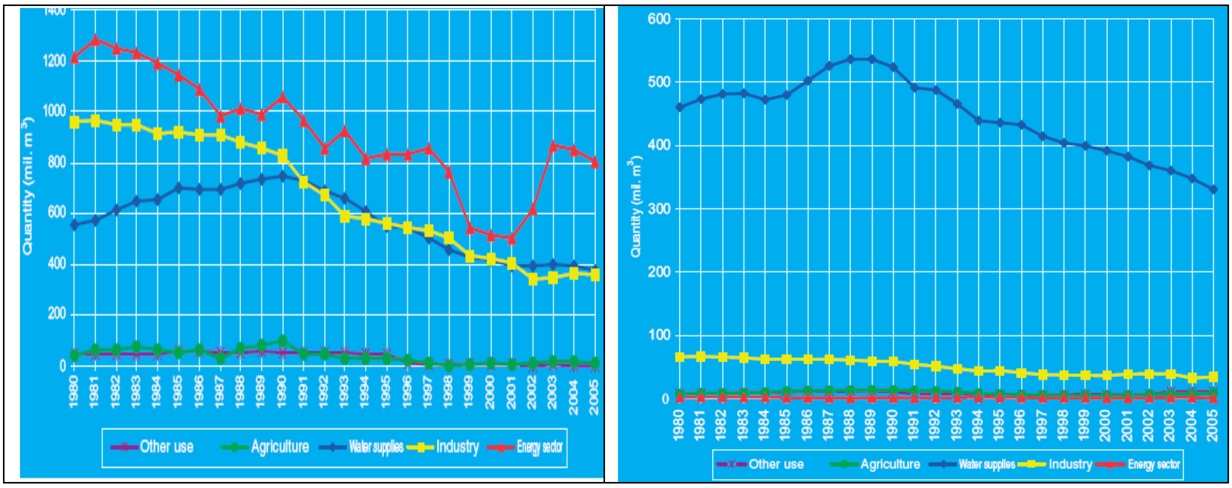
[57] Hochstrat, R., Wintgens, T., Kazner, C., Melin, T., Gebel, J., 2010. *Options for water scarcity and drought management - the role of desalination*, Desalination and Water Treatment, 18 (2010), 96–102. (www.deswater.com)

[58] EU Maritime Affairs *Country Overview and Assessment–Cyprus.*(Accessed 10 December 2011) (http://ec.europa.eu/maritimeaffairs/documentation/studies/documents/cyprus_climate_change_en.pdf)

[59] Ministries of Agriculture and of Environment of the Czech Republic, 2009. *Report on Water Management in the Czech Republic in 2008*. Ministry of Agriculture of the Czech Republic, Prague.

can change if climate change will be taken into consideration. Figure 4.6 shows the abstractions from surface and groundwater for different water sectors.

Figure 4.6 - Development of surface water (left) and groundwater (right) abstractions by categories of water use



Source: Ministries of Agriculture and of Environment of the Czech Republic, 2009

Frantisek Toman, Pavel Spitz and Jiri Filip from the Mendel University of Agriculture and Forestry[60] have found that climate change will play an important role in Czech Republic Agriculture. 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 or 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 Mio m^3. Alternative 2 gives a much more unfavourable situation for the country where irrigation should be applied on an area of 1,085,000 ha which means 35% of arable land. Water demand will be at 1,750 Mio m^3.

Concluding, even though the Czech Republic is not using high amounts of water in agriculture at the moment, climate change will play an important role. **Future predictions show an increase in agricultural water demand of 57 Mio m^3 in the conservative scenario, meaning an increase in the vulnerability of the agricultural sector to WS.**

4.2.6. Vulnerability of water resources to new trends in agriculture and tourism: Murcia Case Study (Spain)

The Segura basin (Figure 4.7) is located in southeast Spain and characterized by intense over-use of its water resources (Zimmer, 2010)[61]. In 1978, water transfer from Tajo to Segura River Basin was

60 Toman, F., Spritz, P., Filip, J. 2008. *Impact of Predicted Climatic Changes on Agriculture and Forestry in the Czech Republic*. Department of Landscape Ecology, Mendel University of Agriculture and Forestry and Research Institute of Soil and Water Conservation.

61 Zimmer, A., 2010. *New water uses in the Segura basin: conflicts around gated communities in Murcia*. Water International, 35:1, 34-48.

initiated, raising the actual surface and groundwater availability in Segura to 1343 hm^3/a. However, there is still a water availability-demand deficit of 416 hm^3/a, which is met through groundwater extraction. As a result, groundwater resources face the serious risk of depletion and degradation. A second transfer from the Ebro River was included in the National Hydrologic Plan in 2001 by the Popular Party of Spain, but cancelled in 2004 after the opposite party won the elections.

The Independent Community of Murcia (Comunidad Autónoma Región de Murcia) covers 59.3% of the Segura basin (Figure 4.2.11), and 98.6% of its territory is drained by the Segura system. Traditionally, the agricultural sector is the major water consumer by 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 presented 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 led to an increase in the population of Murcia with a consequent increase in the household water use.

Figure 4.7 - 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 (in 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 production) conflicts are raised between different social groups and states of administration.

Concluding, Segura Basin and particularly the region of Murcia can be characterized as extremely vulnerable to water scarcity, especially due to the modernization and increase of the agricultural production. 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.

4.2.7. Impact of WSD on Protected Areas: Iberian Aquatic Ecosystems (Spain)

''Las Tablas de Daimiel'' National Park is a natural reserve in south-central Spain that covers 19.28 km^2 in the upper Guadiana basin. It is a Ramsar wetland and the core of UNESCO Biosphere Reserve, called "La Mancha Húmeda". Due to groundwater overexploitation during the last decades, mainly through illegal wells dug by farmers around the park (some of them reach the depth of 100m), the aquifer that once supplied the wetland is now about 20 m below (Ibáñez, Carola, 2010)[62]. 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.

62 Ibáñez, C., Carola, N., 2010. Impacts of Water Scarcity and Drought on Iberian Aquatic Ecosystems, Policy Note 04-0910, September 2010. Water Science and Policy Center.

After the serious events of 2009, EU gave a 10-week time limit to the Spanish Government in order to come up with measures to mitigate the ecological damage. Finally, as a temporary solution water transfer was determined and in January 2010 an underground pipe diverted water from the Tagus River Basin inside the park. Furthermore, intense rainfall in February 2010 managed to partially restore 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 and sustainability of the wetlands are required.

4.2.8. Impacts of water abstraction for hydropower generation: Upper Isar Case Study (Germany)

Since 1923, a major part of the Upper Isar River (Bavaria, Germany) has been diverted to Lake Walchensee at the weir in Krun for hydropower generation (Alpine Convention, 2009)[63]. The river is dammed between the regions Mittenwald and Krun and almost utterly 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 Mio m^3 per year to 0.02 Mio 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 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.

Summing up the previous facts, it is evident that serious controversies are raised in the Upper Isar River regarding the protection of the vulnerable to flood villages, the nature conservation of the protected area and the sustainable functioning of hydropower generation. For the sustainability of this region, a reconsolidation between all different interests is necessary, in order to reach viable and effective solutions.

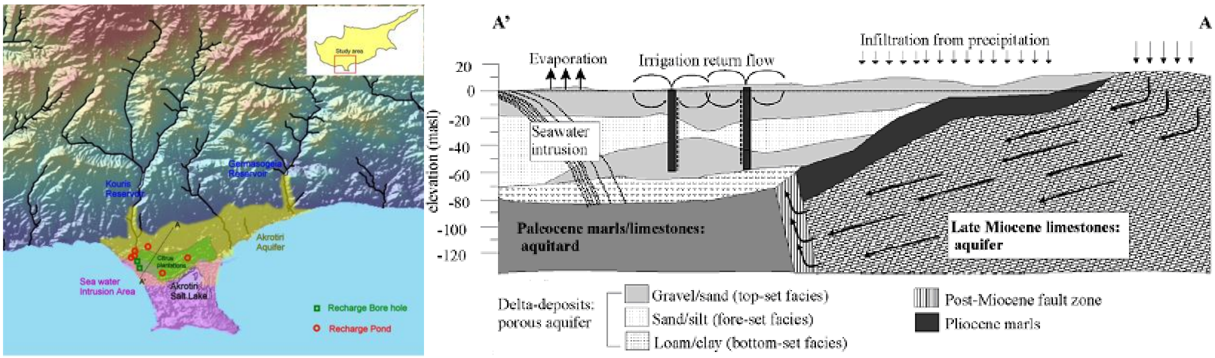
4.2.9. Impacts on Groundwater: Reduced recharge and overexploitation of the Akrotiri aquifer (Cyprus)

The Akrotiri aquifer is located in the southern most part of Cyprus in the Eastern Mediterranean, forming 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 thicknesses varying between 20 and 50 m. The cli-

[63] Alpine Convention. 2009. *Water and Water Management Issues - Report on the State of Alps*. Alpine Signals-Special Edition 2, Permanent Secretariat of the Alpine Convention.

matic 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)[64]. 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 (Figure 4.8)

Figure 4.8 - Location and cross section of the Akrotiri aquifer



Source: Milnes, 2011

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 was abstracted per year in the period 1940-1986. Due to growing water demand the Kouris dam was constructed in 1986, about 10 km 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[65] (2011) summarized the long term water budgets for three periods

	Pre-1940	1940-1986	Post-1986
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

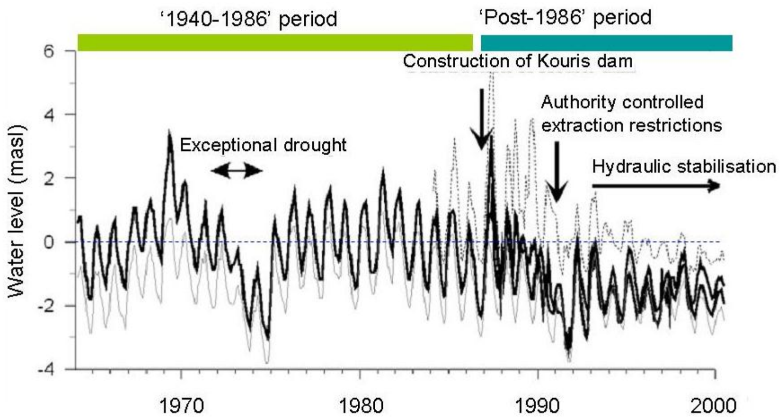
The reduced recharge and increased groundwater abstraction has led to a deficit in the water balance and an enhanced seawater intrusion, which became alarming by the end of the 1980s. Measures were implemented to decrease the groundwater abstraction and increase the recharge through controlled water 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 the last years, the general water table level into the plain stabilized below sea level (Figure 4.9). This slowed down seawater intrusion and groundwater salinisation induced by irrigation but salinisation continues at a slower pace. On the long term water availability is expected to become

64 Aquastress, 2009. Water Stress Mitigation: The AquaStress Case Studies. Booklet produced by the Aquastress consortium, edited by D. Assimacopoulos within the EU FP 6 Aquastress project (Contract n°: 511231).

65 Milnes, E., 2011. Process-based groundwater salinisation risk assessment methodology: Application to the Akrotiri aquifer (Southern Cyprus). Journal of Hydrology 399: 29–47. doi:10.1016/j.jhydrol.2010.12.032

more stressed due to a gradual decrease in the annual precipitation amount and an increase in the water demand.

Figure 4.9 - General water table level in the plain of the Akrotiri aquifer



Source: Milnes, 2011

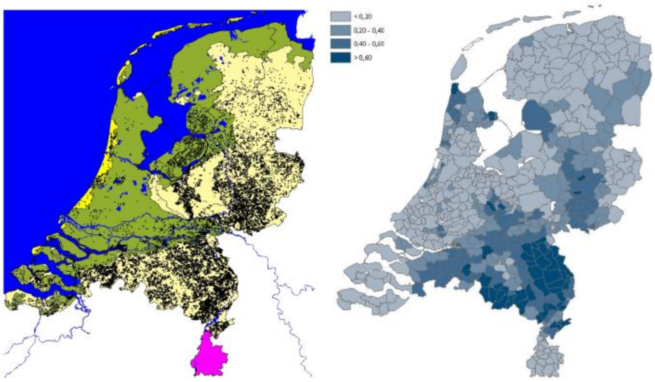
4.2.10. Impacts on small water bodies: Impact of abstraction and irrigation on small surface waters in the Netherlands

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 the precipitation amount (De Louw, 2000)[66]. Although the Netherlands has a high supply of water, also the demands for water are high. One reason 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 a 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 where there is less surface water supply available from the main waters. Here, 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 m3) is low compared to the total amount of water abstraction and mostly originating from groundwater (~65-80%). Irrigation is mostly used for grassland, corn, potato's, vegetables from field production and other crops.

Figure 4.10 - Location of abstraction wells from irrigation (left) and the fraction of irrigated lands compared to the total area of cultivated lands (right)

[66] Louw, P. de, 2000. Abstraction from groundwater affects upward seepage. Informatie, edition groundwater and subsurface 6, april 2000, NITG-TNO, Utrecht (In Dutch).



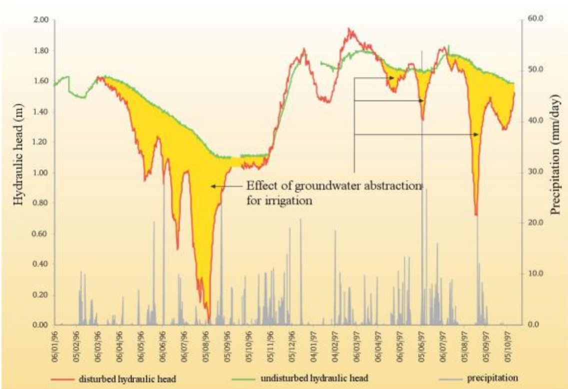
Source: De Louw, 2000

Impact of irrigation

Besides the continuous groundwater abstraction for public drinking water supply and industrial purposes, irrigation can from an extra stress for ecosystems. 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. In drought periods most rivers and brooks are characterized by low flow and groundwater is important to maintain sufficient base flow.

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 compared to 240 million m^3 per year for public water supply and industry. 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 4.11).

Figure 4.11 - Impact of abstraction for irrigation on the hydraulic head



Source: De Louw, 2000

The hydraulic head can be lowered 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 m3. 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 will become reality than the impact of irrigation will increase considerably.

Measures

Irrigation can be banned by regulation of the regional authorities to protect ecosystems. Since the dry year 2003 this has occurred almost on a yearly basis and more pronounced in the year 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 wires are some examples of structural adjustments.

5. Scenarios

This chapter will be will be developed in link to the EEA adaptation report

6. Adaptation Policies and Measures and the progress in their implementation

This chapter will be will be developed in link to the EEA adaptation report

Example of WSD management and mitigation action: The Catchment Abstraction Management Strategies (CAMS)[67] in UK

The Environment Agency of England and Wales has developed Catchment Abstraction Management Strategies (CAMS[68]) to improve the degree of consistency, transparency and clarity of process in the management of water resources. 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[69]. 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 ab-

67 Dunbar, M.J., Acreman, M.C. & Kirk, S. 2004 Environmental flow setting in England and Wales: strategies for managing abstraction in catchments *Journal of the Chartered Institution of Water and Environmental Management*. 18, 1, 5-10

68 Environment Agency. 2010 *Managing Water Abstraction: the Catchment Abstraction Management Strategy Process.* Environment Agency, Bristol, UK. http://publications.environment-agency.gov.uk/pdf/GEHO0310BSBH-E-E.pdf

69 Environment Agency. 2001 *Resource Assessment and Management framework. Report and User Manual (version 2).* W6-066M. Environment Agency, Bristol, UK.

stracted 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 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 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[70]. 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. Fish; 2. Flow characterisation; 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 fish element is defined from fish survey data together with a model that predicts fish communities in UK rivers[71]. Flow characterisation classes are those define for physical water body types in the UK[72]. For macro-invertebrates, a system called LIFE (Lotic invertebrate Index for Flow Evaluation[73]) is employed, this relates flow to an invertebrate community score based on invertebrate samples compared with a target score derived using a statistical model[74].

3. Definition of the environmental flow

Once an AP has been assigned to a particular overall Environmental Flow Indicator, a look-up table is used 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 ecological 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)

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[70] Young, A.R., Allachin, M.I. and Holmes, M.G.R. 2000 Seeing it in Flow Motion: Low Flows 2000. *In Proceedings of the 4th International Conference on Integrating GIS and Environmental modeling*, Banff, Canada, 3-8 September 2000

[71] Cowx, I.G. 2001. *Factors influencing coarse fish populations in rivers*. R&D Publication 18, Environment Agency, Bristol, 146 pp.

[72] Acreman, M.C., Dunbar, M.J., Hannaford, J., Wood, P.J., Holmes, N.J., Cowx, I., Noble, R., Mountford, J.O., King, J., Black, A., Extence, C., Crookall, D. & Aldrick, J. 2008. Developing environmental standards for abstractions from UK rivers to implement the Water Framework Directive *Hydrological Sciences Journal*, 53, 6, 1105-1120

[73] Extence, C.A., Balbi, D.M. Chadd, R.P. River flow indexing using British benthic macro-invertebrates: a framework for setting hydro-ecological objectives. *Regulated Rivers Research and Management,* 1999, 15, 6, 543.

[74] Wright, J.F., Sutcliffe, D.W., Furse, M.T. (eds). 2000 *Assessing the Biological Quality of Fresh Waters: RIVPACS and other techniques.* FBA Special Publication. Freshwater Biological Association, Ambleside.

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.

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 1 shows an example of resource assessment. The black flow duration curve line shows the benchmark 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 critical points on the curves for assessment are Q_{70} and Q_{95}. 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 WFD. HEV is then used to detect trends in low flows and ecological response. Figure 2 is an example from a different AP to that of Figure 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.

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.

Figure 6.1 - Example of CAMS assessment

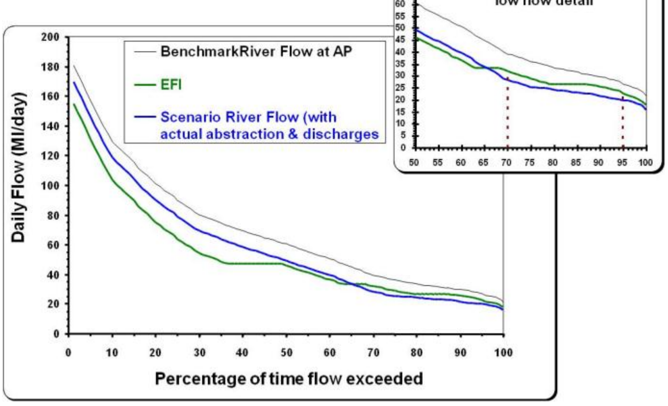
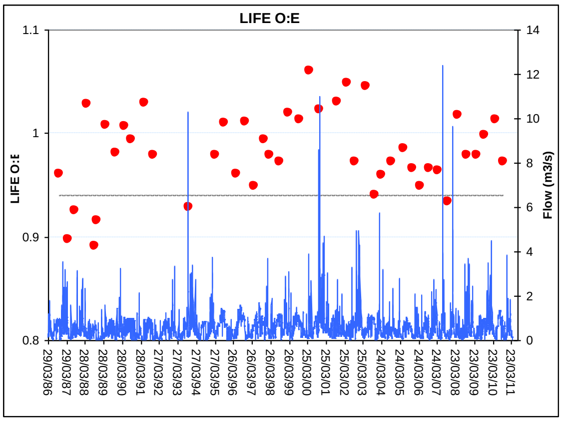


Figure 6.2 - **Example of HEV plot**



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8. Annex: Background Document on the WEI and related data

8.1. Purpose of the background document

The Water Exploitation Index (WEI) has largely been used to assess the prevailing water stress and scarcity conditions in a region, as it depicts the balance between natural renewable water resources and abstraction. The WEI definition is given below:

$$WEI(\%) = \frac{AnnualTotalWaterAbstraction}{AvailableLongtermFreshwater\,\mathrm{Re}\,sources}$$

where,
Available Longterm Freshwater Resources = Precipitation(ltaa) – Actual Evapotranspiration(ltaa) + External Inflow(ltaa)

The warning threshold for the WEI, which distinguishes a non-stressed from a stressed region, is around 20 %. Severe water stress can occur where the WEI exceeds 40 %, indicating unsustainable water use.

The WEI relates to the EEA CSI018 (Use of freshwater resources), while similar indicators, bearing different names and definitions are developed by EU and other initiatives as presented in Table 8.1.

Table 8.1 - Indicators similar to the WEI, developed by EU and other initiatives

Indicator/ Index	Reference	Spatial Scale	Required Data
Water Exploitation Index (WEI)	EEA	Country, some RBs	annual freshwater abstractions, long term annual freshwater resources availability (LTAA)
Intensity of use of water resources	OECD, 2001	country, region	annual freshwater abstractions, total renewable water resources
Index of Watershed Indicators (IWI)	EPA, 2002	watershed	15 condition and vulnerability indicators
Exploitation index of renewable resources	Plan Bleu	country	
Water Stress Index (WSI) per source	EWP Water Stewardship Programme	Site specific	water abstraction/ consumption as percentage of available water per source (%) with the water abstraction volume per source in [m^3/month or season] and average [m^3/year]
Water discharge index (WDI)	EWP Water Stewardship Programme	Site specific	total amount of water discharge [m^3/time period] in relation to total amount of available water body [m^3/time period
Indicator of water scarcity	Heap et al., 1998	country, region	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., 1999	region	time-series of surface runoff (monthly), time-series of groundwater resources (monthly), water demands of domestic, agricultural and industrial sector
Vulnerability of Water Systems	Gleick, 1990	watershed	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	annual water withdrawals, total renewable water resources, GDP per capita, national reservoir storage volume, time-series of precipitation, percentage of external water resources
Water Poverty Index (WPI)	Sullivan, 2002	country, region	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)

While the water abstraction as a percentage of the freshwater resource provides a good picture of the pressures on resources in a simple manner that is easy to communicate and understand, issues related to definitions of the WEI parameters, the temporal and spatial scales of the application, and the data quality and accuracy remain open and in some cases debatable, and can lead to a biased interpretation of the extend and severity of water stress conditions over Europe.

The traditional **spatial scale** of implementation of the WEI (country level) is too aggregated and fails to depict the regional variability within the country (as an example refer to France in Map 3.2). 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. Similarly, the **temporal scale** of implementation (currently the long-term average availability ltaa is considered) can hide water stress conditions which may be evident during some years. The periods for which the long-term average availability is considered are not always harmonised. Additionally due to climate change one can not considered that precipitation conditions of e.g. 1980-2000 are representative in 2012. Using thus ltaa availability can communicate misleading messages, leveraging dry years and confusing the assessment. Furthermore, even an annual scale application could hide stress conditions over some critical months (e.g. summer, as an example refer to Czech Republic-Morava RB in Figure 3.2).

Regarding the **definition of the WEI parameters**, a revision has been introduced with the purpose of better capturing the balance between natural renewable water resources and abstraction, and the true potentially exploitable water, in order to better assess the prevailing water stress conditions in a region. The proposed revised WEI+ aims mainly at redefining the actual potential water to be exploited (i.e. availability), by incorporating **returned water** and **environmental requirements** (either as a parameter, or in the definition of the relevant thresholds), while proposing and application at a **disaggregated spatial scale** (e.g. River Basin, Subbasin, River Basin District, Subunit). The level of stress or relevant water scarcity in a region changes if we subtract an amount of water that is not actually available for abstraction since it needs to be left in the water bodies to maintain their ecological status (in line with WFD) or other legal requirements (e.g. treaties in transboundary rivers). Additionally, one needs to take into account the returned water (i.e. the volume of water that is returned and available for re-use in the catchments either treated or non-treated), which in the case of cooling water for electricity production it may be a significant volume not to be neglected.

Regarding the **data that have been used to calculate the WEI**, different datasets exist, either as products of reporting (e.g. WISE-SoE, EUROSTAT, FAOSTAT) or modelling (e.g. WaterGap, SEEAW water accounts), and are publicly available. This empowers the general public to run various calculations to represent water stress and scarcity, considering each time different assumptions, formulas, data sources (where definitions of parameters are not necessarily matching) and various constraints. Accordingly, the results can be disseminated under different streams and possible misleading messages can be communicated. It is generally accepted that all such calculations bear a level of uncertainty but the risk of misinterpretation of the underlying parameters and outputs may become higher in this case. Thus, it becomes important that the needed clarifications regarding the data are brought up to discussion and a harmonised approach is implemented than can facilitate the correct representation of water scarcity conditions and the accurate interpretation of the results. Assumptions regarding data (gap filling, proxy calculations etc) is not a new problem, it is common in EU, even within a MS among its different agencies who use different models, methodologies etc. The WEI parameters are no exception to that and what we must point out here is the need that under every indicator and parameter a clear statement of the assumptions, calculations and methods should be stated to avoid misinterpretation.

The **main purpose of this background document** is to disseminate to the MSs identified issues around the existing datasets (accuracy, quality, correctness, completeness of data, etc.), open the dialogue towards improving the EU dataflows on water quantity, and find out the key points that need to be accompanied by clarifications so that wrong messages are not communicated. Furthermore, the document wishes to expose the issue that the selection of different scales (e.g. annual vs. ltaa, RBD vs. country) and parameters (e.g. including returned water) into the WEI formula lead to different results and different interpretations of the water stress conditions in Europe, thus careful considerations should be made towards improving the WEI formula on a more solid scientific basis. In this direction work is undertaken within the WFD CIS Expert Group on Water Scarcity and Drought (EG

WSD) and the respective Technical Working Group (TWG) and a document with the advantages and disadvantages of the different options is under preparation.

8.2. WEI at Country level and relevant data issues

Different options of the WEI have been calculated based on WISE-SoE#3 and Eurostat JQ IWA data, to allow inter-comparison in terms of how both the selection of parameters to include and input data affect the results. The options (formulas) of the WEI which have been considered, along with the definition of parameters and data input, are presented in Table 8.2.

Table 8.2 - WEI options and parameters used

$WEIannual(\%) = \frac{AnnualTotalWaterAbstraction}{AnnualFreshwater\ \mathrm{Re}sources}$ ▪ The total annual abstraction includes both surface and groundwater abstractions, excludes hydropower, includes cooling water ▪ Annual Freshwater Resources = Annual Precipitation (P) – Annual Actual Evapotranspiration (ETa) + Annual External Inflow (Ex.Inflow) ▪ Data from the latest available year have been used ▪ Both WISE-SoE#3 and Eurostat data have been used
$WEI(ltaa)(\%) = \frac{AnnualTotalWaterAbstraction}{AvailableLongtermFreshwater\ \mathrm{Re}sources}$ ▪ The total annual abstraction includes both surface and groundwater abstractions, excludes hydropower, includes cooling water ▪ Available Longterm Freshwater Resources = Precipitation(ltaa) – Actual Evapotranspiration(ltaa) + External Inflow(ltaa) ▪ Both WISE-SoE#3 and Eurostat data have been used
$WEIannual\_excl.CoolingWater(\%) = \frac{AnnualTotalWaterAbstraction - CoolingWater}{AnnualFreshwater\ \mathrm{Re}sources}$ ▪ The total annual abstraction includes both surface and groundwater abstractions, excludes hydropower, includes cooling water ▪ Cooling water refers to the volume used for electricity generation (NACE D) ▪ Annual Freshwater Resources = Annual Precipitation (P) – Annual Actual Evapotranspiration (ETa) + Annual External Inflow (Ex.Inflow) ▪ Data from the latest available year have been used ▪ Both WISE-SoE#3 and Eurostat data have been used
$WE(ltaa)\_excl.CoolingWater(\%) = \frac{AnnualTotalWaterAbstraction - CoolingWater}{AvailableLongtermFreshwater\ \mathrm{Re}sources}$ ▪ The total annual abstraction includes both surface and groundwater abstractions, excludes hydropower, includes cooling water ▪ Available Longterm Freshwater Resources = Precipitation(ltaa) – Actual Evapotranspiration(ltaa) + External Inflow(ltaa) ▪ Cooling water refers to the volume used for electricity generation (NACE D) ▪ Both WISE-SoE#3 and Eurostat data have been used

The results of the above options and data combinations are illustrated in Figure 8.1**-** Figure 8.6**. Additionally, the ratio of Actual Evapotranspiration over Precipitation (ETa/P) for both the latest available year and the longterm average have been calcu-**

lated in an effort to estimate data accuracy. The results are presented in Figure 8.7 **-** Figure 8.8**. The data used in the calculations, as well as issues and possible problems identified with regards to the data are summarised in Table 8.3-**

Table 8.4.
Finally, the best available representations of the WEI options at EU scale, based on combination of the most recent data from both WISE-SoE and Eurostat, and correcting obvious data errors (according to expert judgment) illustrated in **Map 8.1- Error! Reference source not found.** .

Figure 8.1 - WEIannual and WEI(ltaa) based on Eurostat data

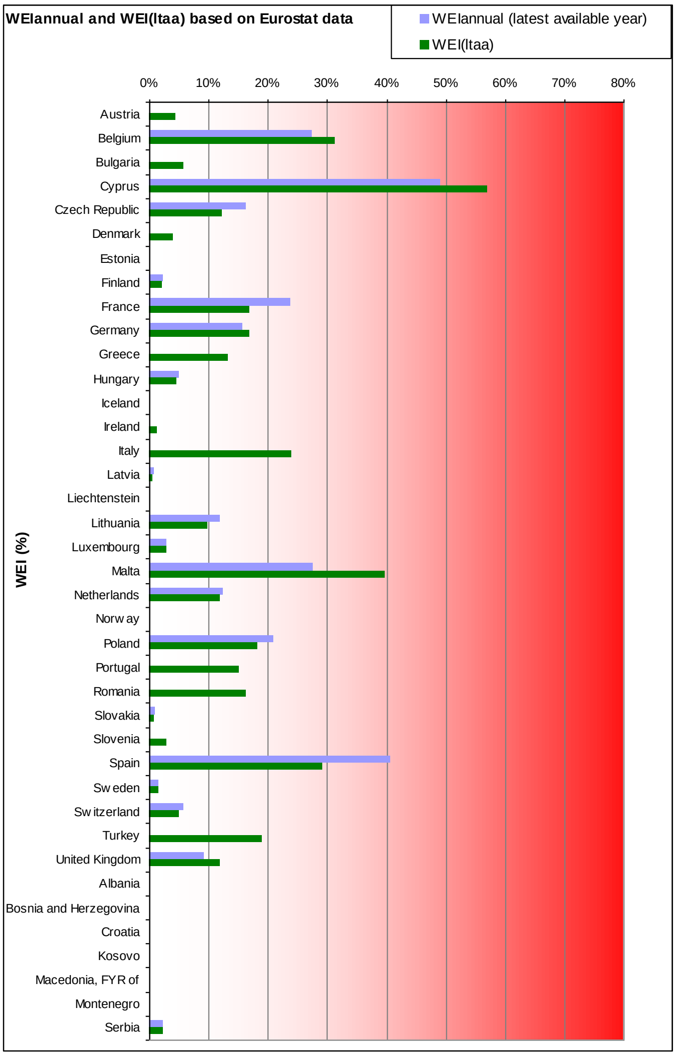


Figure 8.2 - WEIannual and WEI(ltaa) based on WISE-SoE data

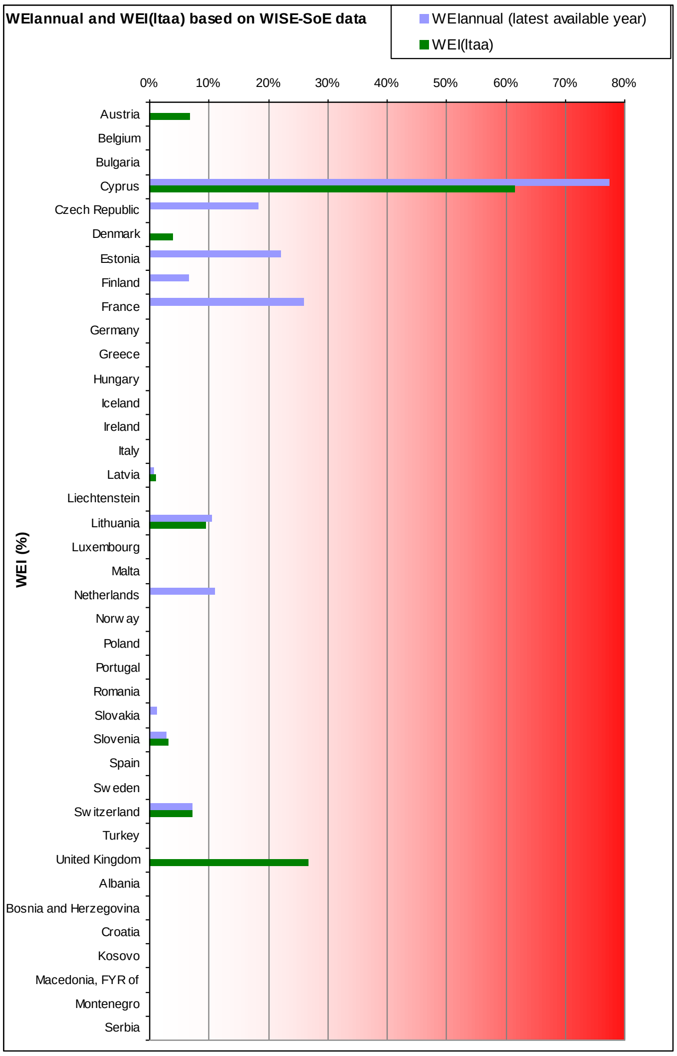


Figure 8.3 - WEIannual considering cooling water as return, based on Eurostat data

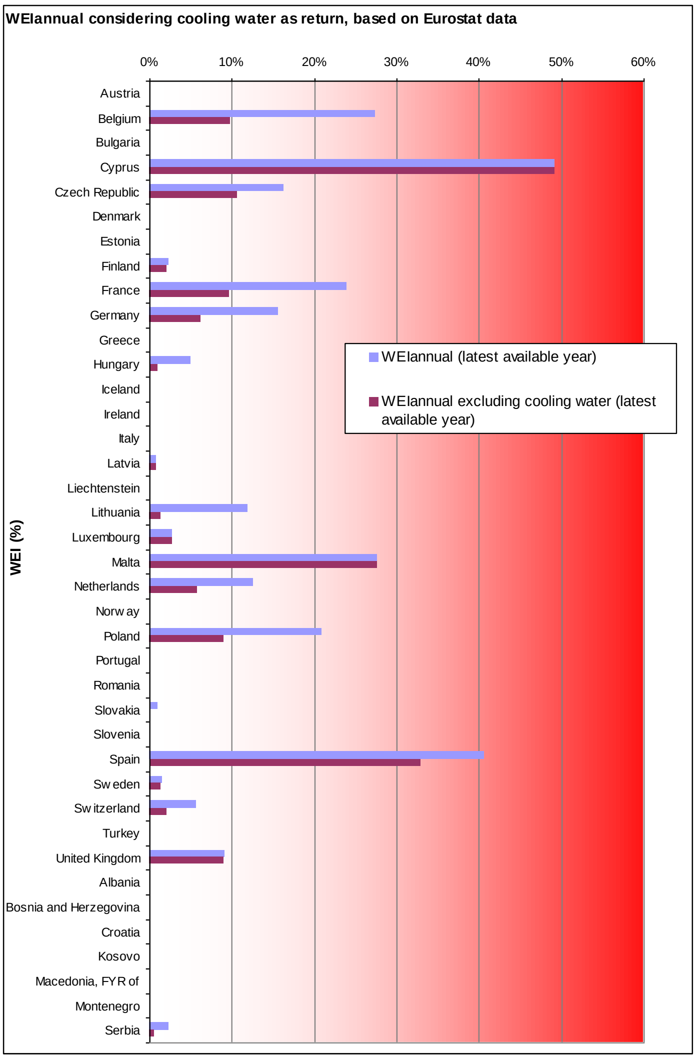


Figure 8.4 - WEI(ltaa) considering cooling-water as return, based on Eurostat data

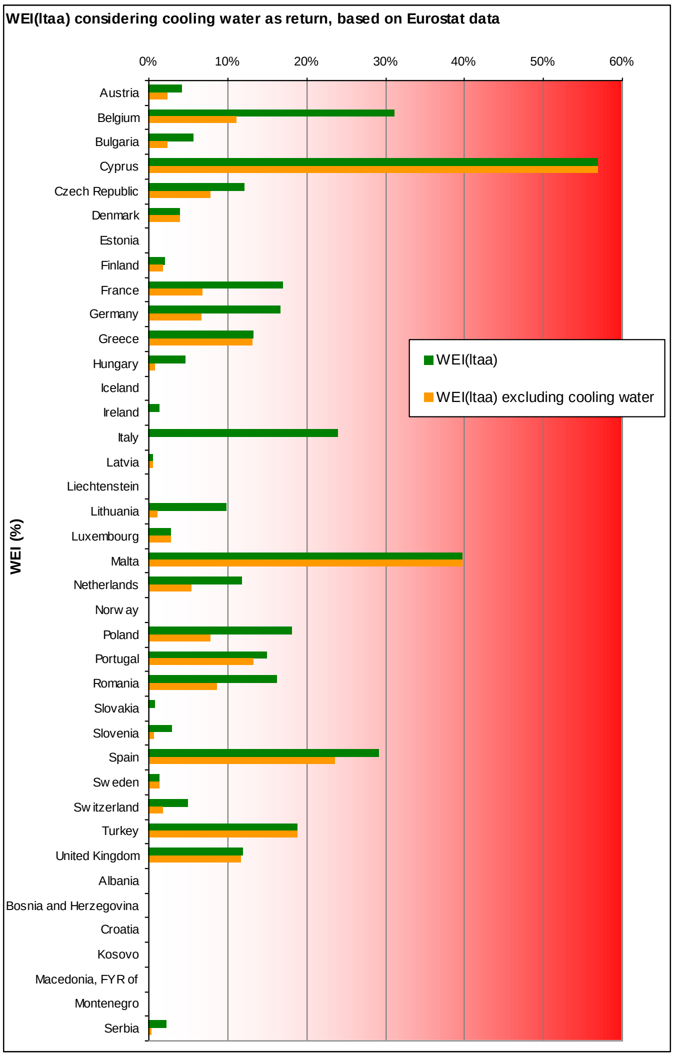


Figure 8.5 - WEIannual considering cooling water as return, based on WISE-SoE data

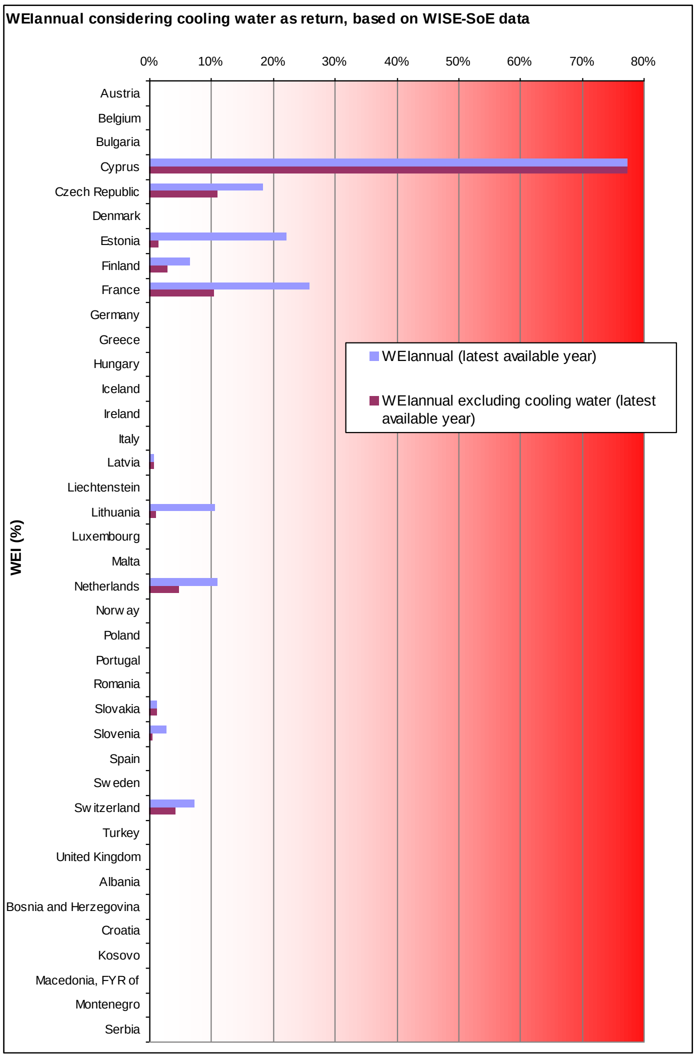


Figure 8.6 - WEI(ltaa) considering cooling-water as return, based on WISE-SoE data

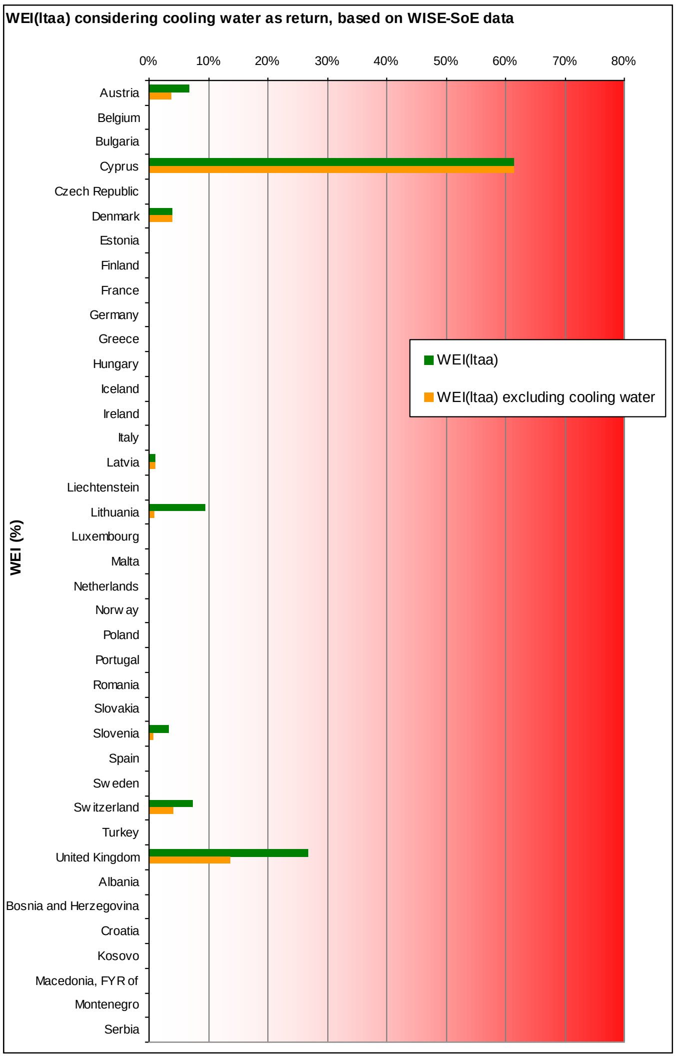


Figure 8.7 – Ratio of Actual Evapotranspiration (ETa) over Precipitation (P) based on Eurostat data

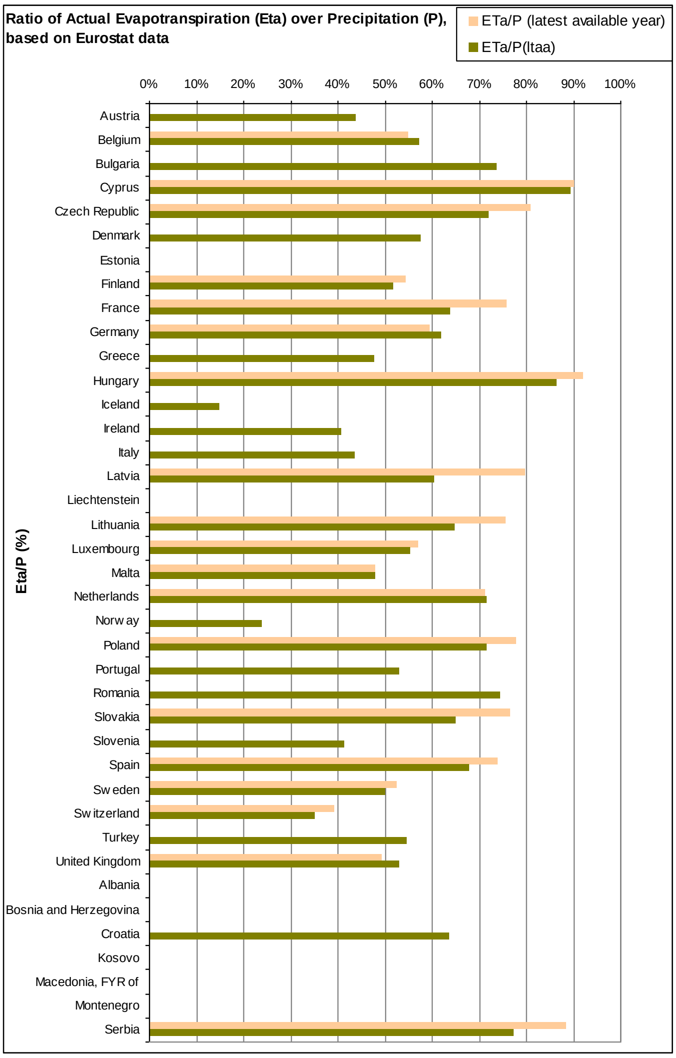


Figure 8.8 - Ratio of Actual Evapotranspiration (ETa) over Precipitation (P) based on WISE-SoE data

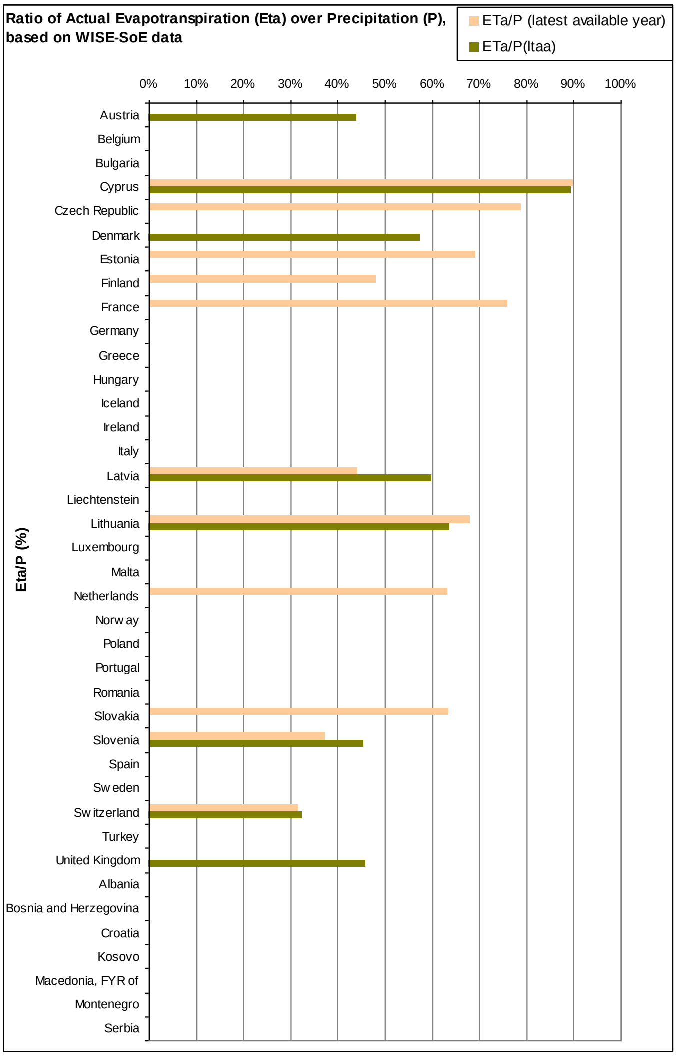


Table 8.3 - Comparison of data reported under EUROSTAT and WISE-SoE relevant to water abstraction

** the data refer to the latest available year reported under each reporting stream*

COUNTRY	CODE	*Reporting stream*	**Total Abstraction** *(including cooling, excluding hydropower)* mio m^3 (Year)	**Abstraction for Hydropower** mio m^3 (Year)	**Abstraction for Cooling** (for generation of electricity) mio m^3 (Year)	**Comments**
Austria	AT	*Eurostat*	3668 (1999)		1620 (1999)	Abstraction for hydropower has not been reported which might be an important figure in the case of Austria.
		WISE-SoE	3668 (1999)		1620 (1999)	
Belgium	BE	*Eurostat*	6217 (2007)		3992 (2007)	
		WISE-SoE				
Bulgaria	BG	*Eurostat*	6121 (2009)		3554 (2009)	
		WISE-SoE	5934 (2010)	17351 (2010)	2978 (2010)	
Cyprus	CY	*Eurostat*	184 (2009)		0 (2009)	
		WISE-SoE	199 (2010)			
Czech Republic	CZ	*Eurostat*	1947 (2009)		683 (2009)	
		WISE-SoE	1998 (2008)		788 (2008)	
Denmark	DK	*Eurostat*	660 (2009)		2 (2009)	
		WISE-SoE	654 (2010)		2 (2010)	
Estonia	EE	*Eurostat*	1388 (2009)		1012 (2009)	
		WISE-SoE	1563 (2006)		1456 (2006)	
Finland	FI	*Eurostat*	2328 (1999)		274 (1999)	Although abstraction data in WISE-SoE and ESTAT refer to different years, the differences are high, especially in cooling water, and some checking is needed.
		WISE-SoE	6562 (2006)		3618 (2006)	
France	FR	*Eurostat*	31615 (2007)		18810 (2007)	
		WISE-SoE	31615 (2007)		18810 (2007)	
Germany	DE	*Eurostat*	32301 (2007)		19480 (2007)	
		WISE-SoE				

Greece	GR	*Eurostat*	9539 (2007)		100 (2007)	
		WISE-SoE				
Hungary	HU	*Eurostat*	5432 (2008)		4349 (2008)	
		WISE-SoE				
Iceland	IS	*Eurostat*	165 (2005)		0 (2005)	
		WISE-SoE				
Ireland	IE	*Eurostat*	730 (2007)			Abstraction data reported under WISE-SoE and ESTAT refer to the same year, yet the difference in mumbers is vey high. It might be the case that cooling water has not been included in ESTAT data, additional checking is needed.
		WISE-SoE	16882 (2007)		16296 (2007)	
Italy	IT	*Eurostat*	41982 (1998)			
		WISE-SoE				
Latvia	LV	*Eurostat*	211 (2007)		2 (2007)	
		WISE-SoE	375 (2010)		3 (2010)	
Liechten-stein	LI	*Eurostat*				
		WISE-SoE				
Lithuania	LT	*Eurostat*	2412 (2009)		2138 (2009)	
		WISE-SoE	2381 (2009)	2977 (2009)	2142 (2009)	
Luxembourg	LU	*Eurostat*	47 (2009)		0 (2009)	
		WISE-SoE				
Malta	MT	*Eurostat*	31 (2009)		0 (2009)	
		WISE-SoE				
Netherlands	NL	*Eurostat*	10606 (2008)		5697 (2008)	
		WISE-SoE	10826 (2007)		6069 (2007)	
Norway	NO	*Eurostat*				
		WISE-SoE				
Poland	PO	*Eurostat*	11517 (2009)		6549 (2009)	
		WISE-SoE				

Portugal	PT	*Eurostat*	11090 (1998)	1237 (1998)	Although abstraction data in WISE-SoE and ESTAT refer to different years, the differences are high, the WISE-SoE number looks very small, and some checking is needed.
		WISE-SoE	915 (2006)		
Romania	RO	*Eurostat*	6876 (2009)	3185 (2009)	
		WISE-SoE	6219 (2010)		
Slovakia	SK	*Eurostat*	688 (2007)		Abstraction data reported under WISE-SoE and ESTAT refer to one year apart, yet the difference in mumbers is high. Additional checking is needed.
		WISE-SoE	1258 (2006)		
Slovenia	SI	*Eurostat*	943 (2009)	726 (2009)	
		WISE-SoE	1058 (2010)	840 (2010)	
Spain	ES	*Eurostat*	32466 (2008)	6230 (2008)	
		WISE-SoE			
Sweden	SE	*Eurostat*	2630 (2007)	103 (2007)	
		WISE-SoE			
Switzerland	CH	*Eurostat*	2660 (2006)	1680 (2006)	Abstraction for hydropower has not been reported. It may help clarify whether the differencet in total abstraction between WISE-SoE and ESTAT is due to this parameter. Checking is recommended.
		WISE-SoE	3903 (2007)	1682 (2007)	
Turkey	TR	*Eurostat*	44450 (2001)	85 (2001)	
		WISE-SoE			
United Kingdom	UK	*Eurostat*	8347 (2008)	157 (2008)	ESTAT reporting refers to England & Wales, while WISE-SoE refers to the whole UK. Nevertheless the differences in Total Abstraction and abstraction for cooling water are very large, while the differences in the Precipitation and ETa values are minor. Checking is needed.
		WISE-SoE	21406 (2001)	10479 (2001)	
Albania	AL	*Eurostat*			
		WISE-SoE			
Bosnia and Herzegovina	BA	*Eurostat*	339 (2009)		
		WISE-SoE			

Croatia		*Eurostat*				
		WISE-SoE				
Kosovo		*Eurostat*				
		WISE-SoE				
Macedonia, FYR of	MK	*Eurostat*	1047 (2009)		18 (2009)	
		WISE-SoE	11415 (2010)	52271 (2010)	234 (2010)	
Montenegro		*Eurostat*				
		WISE-SoE				
Serbia	RS	*Eurostat*	4121 (2009)		3266 (2009)	
		WISE-SoE				

Table 8.4 - Comparison of data reported under EUROSTAT and WISE-SoE relevant to water availability

** the data refer to the latest available year reported under each reporting stream*

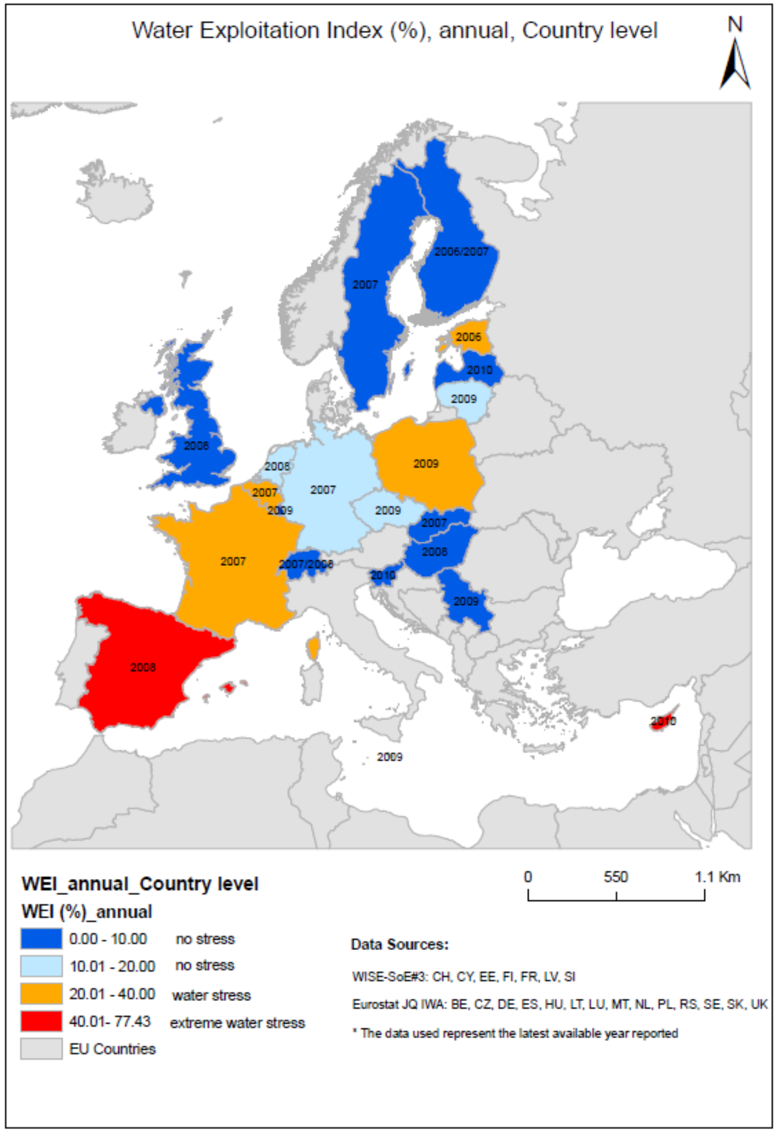
COUNTRY	CODE	Reporting stream	Precipitation (P) mio m^3 (Year)	Actual Evapo-traspiration (Eta) mio m^3 (Year)	External Inflow mio m^3 (Year)	P(Itaa) mio m^3	Eta(Itaa) mio m^3	External Inflow(Itaa) mio m^3	Comments
Austria	AT	*Eurostat*				98000	43000	29000	
		WISE-SoE				95846 (1961-1990)	42152 (1961-1990)		
Belgium	BE	*Eurostat*	31476 (2007)	17303 (2007)	8543 (2007)	28887	16561	7606	
		WISE-SoE							
Bulgaria	BG	*Eurostat*				68598	50513	89141	
		WISE-SoE				70100 (1971-2008)			
Cyprus	CY	*Eurostat*	3745 (2009)	3371 (2009)	0 (2009)	3046	2723	0	Precipitation and Eta differ by about 30% in 2009 and 2010, but high variability of these parameters is normal in Cyprus.
		WISE-SoE	2570 (2010)	2313 (2010)	0 (2010)	3046 (1980-2009)	2723 (1980-2009)		
Czech Republic	CZ	*Eurostat*	59046 (2009)	47826 (2009)	713 (2009)	54653	39416	740	The value of Eta seems very high (ratio of Eta/P = 80%). Attention is needed on whether the reported data refer to the potential evapotranspiration (PET) and not the actual (ETa). Checking is recommended.
		WISE-SoE	49105 (2008)	38689 (2008)	485 (2008)				
Denmark	DK	*Eurostat*				38485	22145	0	
		WISE-SoE	35791 (2007)		0 (2005)				
Estonia	EE	*Eurostat*				29018			
		WISE-SoE	22912 (2006)	15879 (2006)					
Finland	FI	*Eurostat*	209600 (1999)	114000 (1999)	3300 (1999)	222000	115000	3200	
		WISE-SoE	185000 (2007)	89000 (2007)	3000 (2007)				
France	FR	*Eurostat*	506416 (2007)	384848 (2007)		485686	310393	11000	
		WISE-SoE	506416 (2007)	384848 (2007)					

Germany	DE	*Eurostat*	333000 (2007)	198000 (2007)	71000 (2007)	307000	190000	75000	
		WISE-SoE							
Greece	GR	*Eurostat*				115000	55000	12000	
		WISE-SoE							
Hungary	HU	*Eurostat*	56451 (2008)	52008 (2008)	105525 (2008)	55707	48174	108897	The value of Eta seems extremely high (ratio of Eta/P = 92%). Attention is needed on whether the reported data refer to the potential evapotranspiration (PET) and not the actual (ETa). If the Eta value is not correctly reported the calculated Internal Flow for HU (= P - ETa) will be very low. Checking is needed.
		WISE-SoE							
Iceland	IS	*Eurostat*				200000	30000	0	
		WISE-SoE							
Ireland	IE	*Eurostat*				80000	32500	3473	
		WISE-SoE							
Italy	IT	*Eurostat*				296000	129000	8000	
		WISE-SoE							
Latvia	LV	*Eurostat*	48579 (2007)	38700 (2007)	16597 (2007)	42701	25800	16830	The ratio Eta/P reported in ESTAT is 79.7% which seems to be a bit hugh for Latvia. In WISE-SoE this ratio (although it refers to a later year) is 44.3% which seems more logic. Also the LTAA value of ETa seems to be lower and closer to the WISE-SoE value in 2010. Attention is needed on whether the reported data in ESTAT refer to the potential evapotranspiration (PET) and not the actual (ETa). Checking is recommended.
		WISE-SoE	54299 (2010)	24076 (2010)	21454 (2010)	42476 (1961-2005)	25431 (1961-2005)	16830 (1961-2005)	
Liechtenstein	LI	*Eurostat*							
		WISE-SoE							
Lithuania	LT	*Eurostat*	46871 (2009)	35433 (2009)	8734 (2009)	44010	28500	8990	The values of Eta seem a bit high (ratio of Eta/P = 70% approximately). Also the LTAA value of ETa in ESTAT seems to be lower. Attention is needed on whether the reported data refer to the potential evapotranspiration (PET) and not the actual (ETa). Checking is recommended.
		WISE-SoE	44502 (2008)	30277 (2008)	8249 (2008)	44078	28115	8932	

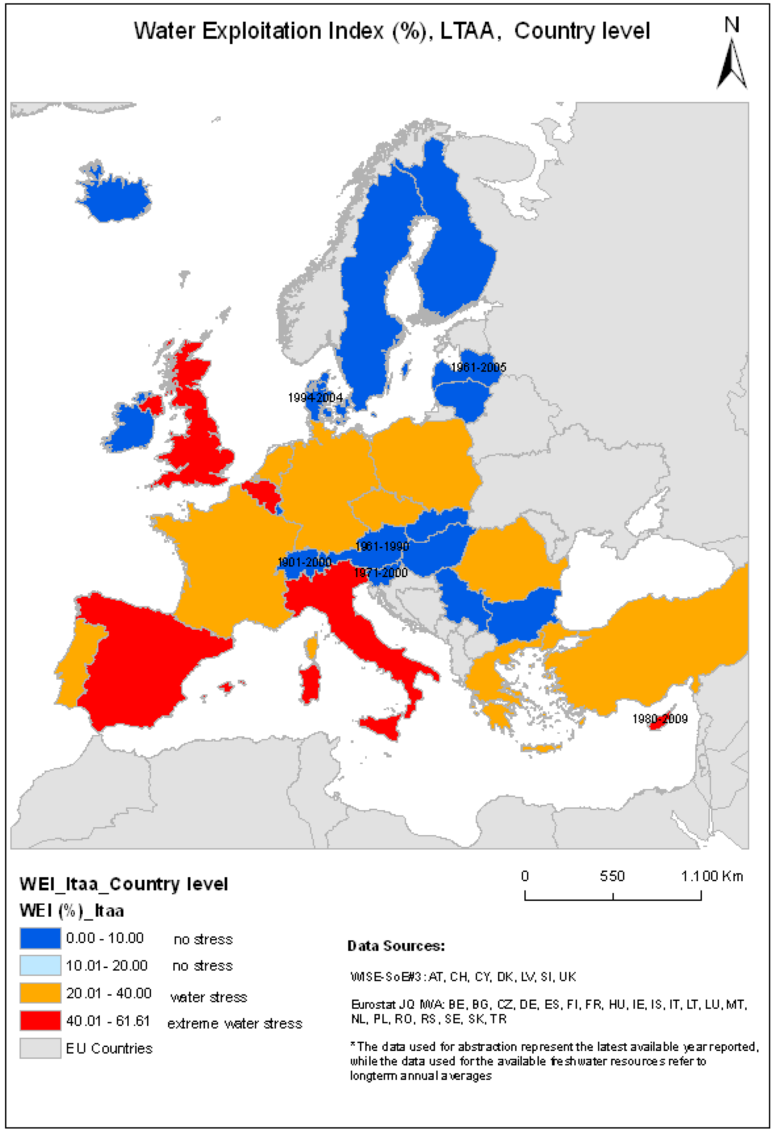
Luxem-bourg	LU	*Eurostat*	2156 (2009)	1229 (2009)	739 (2009)	2030	1125	739	
		WISE-SoE							
Malta	MT	*Eurostat*	215 (2009)	103 (2009)	0 (2009)	150	72	0	
		WISE-SoE							
Nether-lands	NL	*Eurostat*	30929 (2008)	22053 (2008)	75738 (2008)	29770	21290	81200	In WISE-SoE a value of 21703mio m3 has been re-ported in 2007 as potential evapotranspiration PET. In ESTAT a similar value (22053 mio m3) has been reported in 2008 as actual Eta. The ESTAT value seems too high to be the Eta (since it results in a ratio of Eta/P = 71.3%) and it probably reflects the potential ET (PET) instead. Attention is needed not to confuse ETa and PET, and the data need to be checked.
		WISE-SoE	34366 (2007)		85317 (2007)				
Norway	NO	*Eurostat*				470671	112000	12191	
		WISE-SoE							
Poland	PO	*Eurostat*	211370 (2009)	164716 (2009)	8489 (2009)	193100	138300	8300	The value of Eta seems very high (ratio of Eta/P = 78%). Attention is needed on whether the reported data refer to the potential evapotranspiration (PET) and not the actual (ETa). Checking is needed.
		WISE-SoE							
Portugal	PT	*Eurostat*				82164	43571	35000	
		WISE-SoE	74138 (2006)			86616 (1978-2006)			
Romania	RO	*Eurostat*				154000	114585	2878	
		WISE-SoE							
Slovakia	SK	*Eurostat*	39460 (2007)	30196 (2007)	67252 (2007)	37352	24278	67252	The value of Eta reported in ESTAT in 2007 seems very high (ratio of Eta/P = 76.5%). In WISE-SoE the valu is lower and the corresponding ration ETa/P = 63.5%. Attention is needed on whether the reported data refer to the potential evapotranspiration (PET) and not the actual (ETa). Checking is needed.
		WISE-SoE	36310 (2006)	23046 (2006)	86341 (2006)				
Slovenia	SI	*Eurostat*				31746	13150	13496	
		WISE-SoE	37827 (2010)	14097 (2010)	14172 (2010)	32040 (1971-2000)	14550 (1971-2000)	14172 (1971-2000)	

Spain	ES	*Eurostat*	305174 (2008)	225420 (2008)	0 (2008)	346527	235394	0
		WISE-SoE						
Sweden	SE	*Eurostat*	340484 (2007)	179160 (2007)	14275 (2007)	337538	169384	13663
		WISE-SoE						
Switzer-land	CH	*Eurostat*	56696 (2006)	22325 (2006)	12403 (2006)	61594	21603	12798
		WISE-SoE	59374 (2008)	18911 (2008)	13146 (2008)	59103 (1901-2000)	19159 (1901-2000)	13146 (1901-2000)
Turkey	TR	*Eurostat*				501000	273600	6900
		WISE-SoE						
United Kingdom	UK	*Eurostat*	168877 (2008)	83262 (2008)	5680 (2008)	140747	74757	3658
		WISE-SoE				148135 (1960-1990)	68167 (1960-1990)	
Albania	AL	*Eurostat*						
		WISE-SoE						
Bosnia & Herze-govina	BA	*Eurostat*	66277 (2009)					
		WISE-SoE						
Croatia		*Eurostat*				63139	40132	
		WISE-SoE						
Kosovo		*Eurostat*						
		WISE-SoE						
Macedo-nia, FYR of	MK	*Eurostat*	14528 (2009)		1014 (2009)	19533		1014
		WISE-SoE						
Montene-gro		*Eurostat*						
		WISE-SoE						
Serbia	RS	*Eurostat*	59320 (2009)	52400 (2009)	169130 (2009)	56115	43339	162600
		WISE-SoE						

Map 8.1 – WEIannual at Country level



Map 8.2 – WEI(ltaa) at Country level



Map 8.3 – WEIannual_excluding cooling water (Nace D) at Country level

The map will be finalised on Thursday

Map 8.4 – WEI(ltaa)_excluding cooling water (Nace D) at Country level

8.3. WEI at River Basin District (RBD) and Sunbunit (SU) level and relevant data issues

Similar structure as the Country level

8.4. Main conclusions and actions required