Climate ≈ water

Bridging the gap between adaptation strategies of climate change impacts and European water policies

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WP2
Analysis and synthesis of water related impacts

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Aim

- Aim of WP2 was to provide an overview of the main impacts, already observed, or that ar likely to occur in the next years, caused by climate change (CC) on the European waters.

- WP2 consisted in performing an extreme synthesis of a considerable number of papers processed with reference to practically all the impacts occurring on the water sector as a consequence of climate change.

- This synthesis was performed based on the two sub-work package reports, one on the impacts on the society and economy (P8 - UNILEI) and the other on the impacts on nature (P7 – UNIVIEN.FE) which are, in turn, based on the task leader reports and on the thematic focus reports.

- It is strongly recommended to consult the thematic focus reports because they include considerations concerning adaptation strategies, policy implications and research needs, referred to individual impacts, which may help in the preparation of documents for the next work packages (i.e. WP3, WP4 and WP5).

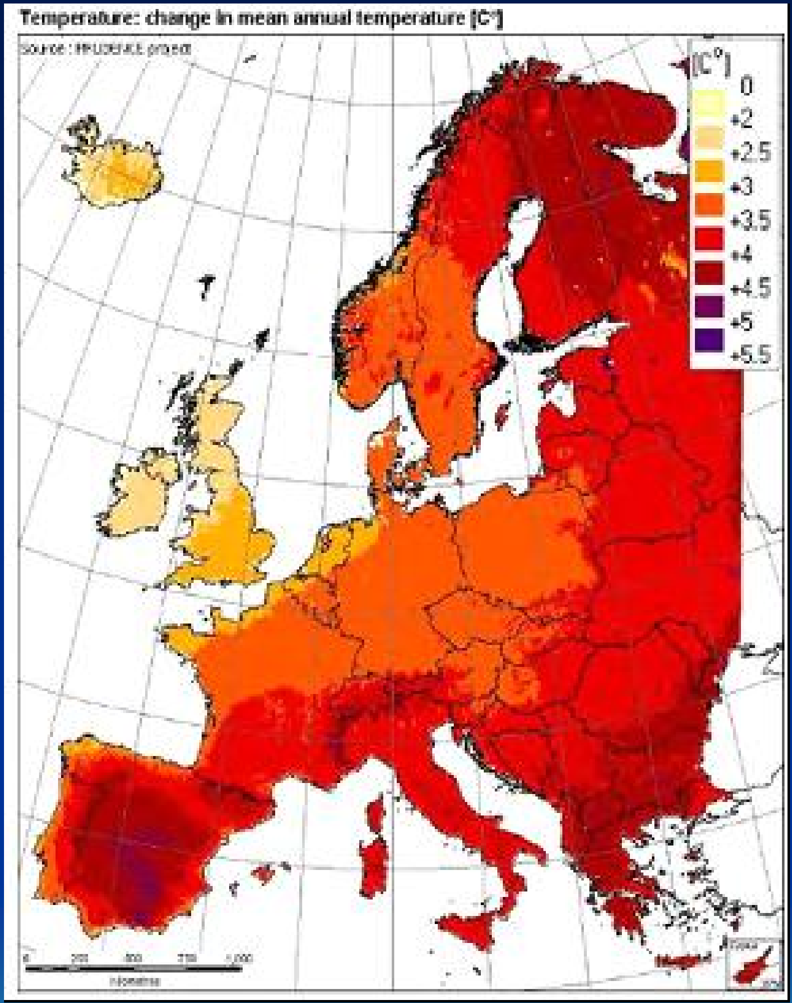
The past

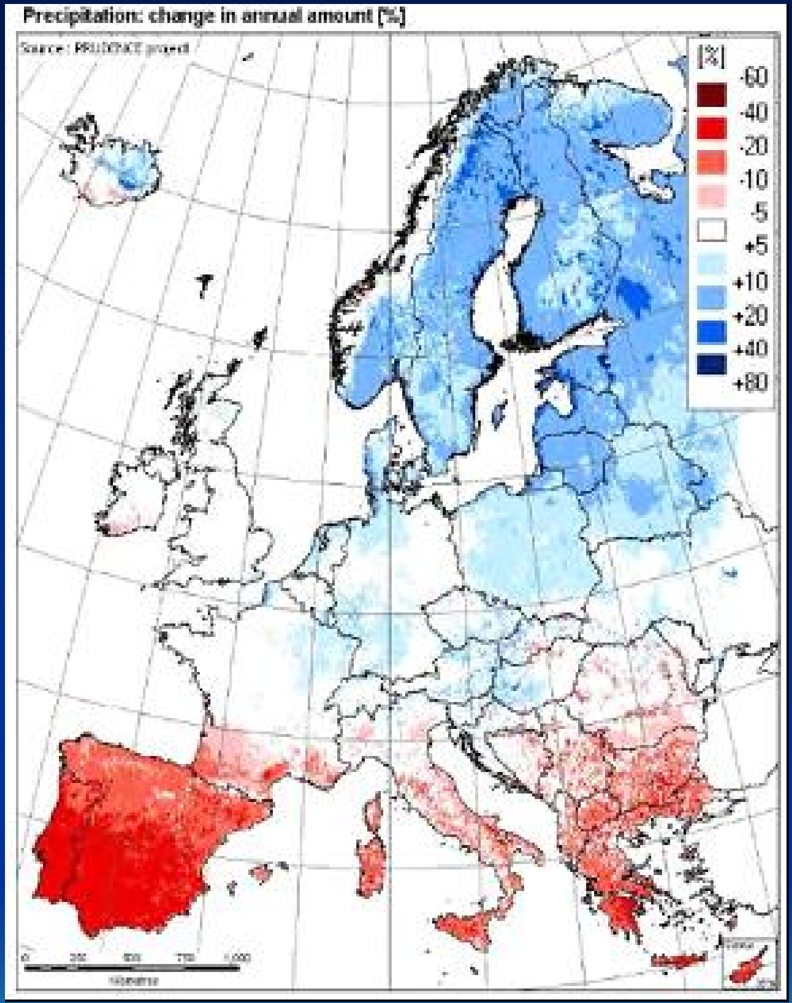
The Earth's average surface temperature has risen by 0.76 °C since 1850. Most of the warming over the past 50 years is very likely to have been caused by emissions of carbon dioxide (CO_2) and other 'greenhouse gases' from human activities.

The future

There are numerous indications that the climate change (mainly precipitation and temperature change) will assume different charcteristics in different parts of Europe.

The future





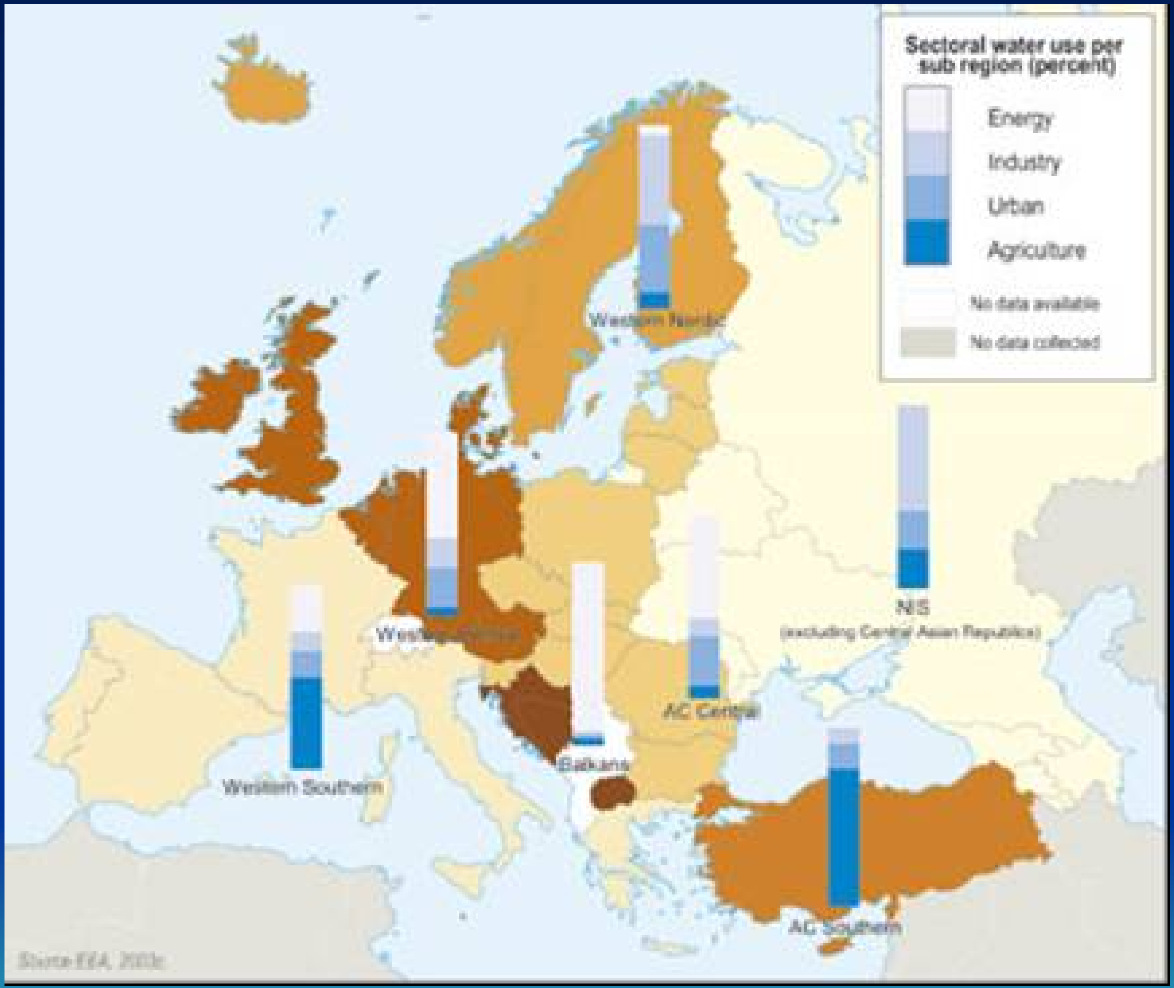
Modelling of Regional IPCCA2 Changes: Possible Temperature (left) and precipitation (right). According to Scenario. Source: Prudence Project

Water use

On average, 42% of total water abstraction in Europe is used for agriculture, 23% for industry, 18% for urban use and 18% for energy production.

Nevertheless it has to be taken into account that sectoral water use changes considerably across Europe.

Water use



Sectoral water uses in different parts of Europe. After: EEA, 2003.

EEA Indicator Fact Sheet: Sectoral water use. http://themes.eea.eu.int/Specific_media/water/indicators/WQ02,2003.1003

WP2 - Water impacts

2.1 Impacts on society and economy

<u>2.1.1 Direct Impacts</u>

- Water supply
- Floods and excess water
- Water quality
- Drought and water scarcity

<u>2.1.2. Indirect Impacts</u>

- Water management
- Agriculture
- Navigation
- Hydropower and nuclear power generation
- Industrial production
- Tourism
- Land use planning

2.2 Impacts on nature

2.2.1 Aquatic ecosystems

2.2.2 Terrestrial ecosystems

2.2.3 Terrestrial-aquatic ecotones

IMPACTS - Water Supply

Number of people at risk from increasing water stress:

- between 0.4 billion and 1.7 billion by the 2020s,
- between 1.0 billion and 2.0 billion by the 2050s,
- between 1.1 billion and 3.2 billion by the 2080s.

Locations most at risk of freshwater supply problems due to climate change:

small islands, arid and semi-arid developing countries, regions whose freshwater is supplied by rivers fed by glacial melt or seasonal snowmelt, countries with a high proportion of coastal lowlands and coastal cities.

IMPACTS - Water Supply

Fresh water (1)

More annual runoff caused by increased precipitation is likely in the high latitudes.

- In case precipitation increase consists of more intense and less frequent rainfall, increased contamination of surface water by runoff, especially by eroded soil, microorganisms, pesticides and fertilizers can occur.

- Always in case of occurrence of more intense and less frequent rainfall, if there is inadequate storage capacity to contain runoff, water supplies could decline, even with increased precipitation.

In contrast, some lower latitude basins may experience large reductions in runoff and increased water shortages as a result of a combination of increased evaporation and decreased precipitation.

IMPACTS - Water Supply
Fresh water (2)

The effects of climate change are likely to be felt also in temperate areas. For example, variability in precipitation and temperature also accounts for some changes in the hydrological characteristics of European river basins.

Predictions about hydrology are difficult in Europe because anthropogenic factors, such as changes in land-use patterns and an increasing proportion of impermeable areas, strongly influence the European hydrological cycle.

IMPACTS - Water Supply

Fresh water (3)

With particular reference to the Mediterranean region, it has been reported that among the causes of an increased water demand there is mass tourism. Tourist water use is, in fact, generally higher than water use by residents.

The worsening of water quality may also be caused by the diminished ability to dilute pollutants of many water bodies. This impact can be caused by the climate change through the already mentioned decreased flow occurring in some water bodies, or it can be the consequence of augmented abstractions for agricultural, but also for municipal or industrial purposes indirectly induced by higher temperatures.

IMPACTS - Water Supply
Fresh water (4)

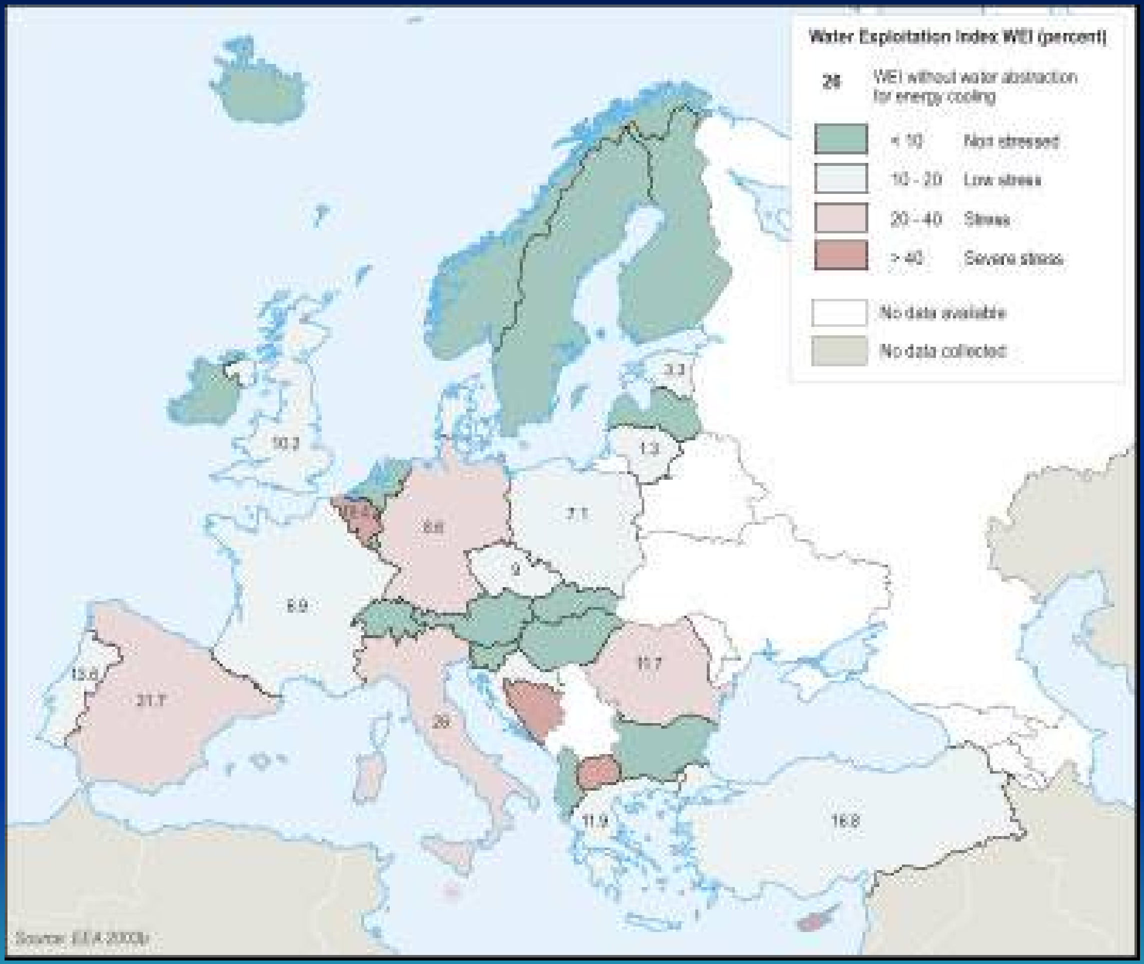
All the above mentioned consequences of the climate change may impair water supply services that will have to cope with the challenge to satisfy consumer demand during periods of intensified water shortages.

Such limitations in the availability of clean and fresh water could result in difficulties in achieving the goal of improved safe access to drinking water, in conflicts among different users.

The increased frequency of extreme precipitation events may put under pressure sewage networks.

Another problem anticipated by some of the referenced documents is that the poorer water quality consequence of the climate change, will require more robust water treatment measures.

WATER EXPLOITATION INDEX



The Water Exploitation Index (WEI) in a country is the mean annual total demand for freshwater divided by the long-term average freshwater resources. It gives an indication of how the total water demand puts pressure on the water resource.

IMPACTS - Water Supply
Groundwater (1)

Groundwater is a major source of drinking water all over Europe, and thus the state of groundwater in terms of quality and quantity is of vital importance.

Nevertheless, the effects of climate change on groundwater (for example changes in the rates of groundwater recharge) are almost undetected.

Climate changes, will lead to land and soil degradation, more frequent floods, rising sea levels, increasing aridity. All these modifications have a direct effect on both groundwater quality and quantity.

IMPACTS - Water Supply
Groundwater (2)

Decreasing groundwater recharge from surface water supplies may be directly caused by climate change. Nevertheless, also increased groundwater withdrawals due to higher temperatures and lower precipitation may be responsible for lower groundwater levels.

Whichever the cause, imbalance between demand and groundwater availability becomes most acute when abstraction occurs at times of prolonged dry periods or drought.

Exploitation of groundwater sources beyond a sustainable level can affect the environment (loss of wetlands and effects on river ecosystems) and reduce the future availability of the resource.

IMPACTS - Water Supply

Groundwater (3)

Many aquifers, exert a strong influence on river flows. For example, in summer, many rivers are dependent on the groundwater base flow contribution to provide a minimum flow.

Lower groundwater levels may, therefore, endanger river-dependent functions (including water supply from surface water abstractions).

As a result of climate change, in many aquifers of the world the spring recharge shifts towards winter and summer recharge declines.

IMPACTS - Water Supply

Seawater - Coastal regions (1)

Melting ice and thermal expansion of oceans are the key factors driving sea level rise. In addition to exposing coastlines, where the majority of the human population live, to greater erosion and flooding pressures, rising sea levels will also lead to salt water contamination of groundwater supplies, threatening the quality and quantity of freshwater access to large percentages of the population.

Nevertheless, the main cause of saline intrusion is commonly regarded not to be the climate change, but an excessive groundwater abstraction from a coastal aquifer.

IMPACTS - Water Supply
Seawater - Coastal regions (2)

Because of its high salt content, about 2% of seawater mixed with freshwater makes the water unusable in terms of drinking water standards, also because conventional treatment methods do not remove the salt.

A small amount of intrusion, therefore, can jeopardise the use of an aquifer for water supply. Due to the long residence time of groundwater, once contaminated with seawater, an aquifer can remain contaminated for decades.

Whichever the cause, radical changes to the freshwater hydrology of coastal areas, caused by saltwater intrusion, would threaten many coastal region's freshwater supplies. In these conditions, costly water supply projects, such as desalination plants, pipelines, and dams will become more economically attractive.

Whilst the problem is most acute in Mediterranean coastal regions, saline intrusion also occurs in Northern Europe.

IMPACTS - Floods and excess water

• Annual runoff will increase in the Atlantic and northern Europe (9-20% by 2070 A2 and B2 SRES scenarios) and decrease in the Mediterranean, central and Eastern Europe.

• The winter flood risk in northern Europe will increase by 2020, whilst the risk of flash floods will increase throughout Europe and risk of snowmelt floods will shift from spring to winter.

• Not only the magnitude but the frequency, timing, spatial extent and the temporal duration of the floods are also likely to change.

• Annual damage from floods is expected to increase in much of western, central and eastern Europe as well as in Italy and northern Spain and significantly decrease in north-eastern Europe.

• Also flooding caused by sea level rise should be considered.

IMPACTS - Water quality

- Temperature rise, decreased flow and higher nutrient loads in the summer will affect the rates of all chemical and ecological processes, resulting in accelerated eutrophication and decreased oxygen content.
- Deterioration in terms of priority pollutants (e.g. heavy metals) and also pathogens is likely to occur. This, in turn may result in serious health risk (mainly among bathers of natural water bodies);
- Deterioration of groundwater quality caused by altered precipitation and runoff conditions;

IMPACTS - Drought and water scarcity

Drought may occur independently on CC, but it can be greatly aggravated by it.

Drought in itself represents a direct impact of CC on water resources; in addition, it can be also responsible for indirect impacts:

Environmental impacts of drought:
- Damage to animal species
- Damage to plant communities (loss of biodiversity, loss of trees).
- Hydrological effects

Economic impacts of droughts:
- Losses to agricultural and livestock producers
- Loss from timber production
- Loss from fishery production

Social impacts of drought:
- Health
- Increased conflicts
- Reduced quality of life

IMPACTS - Water management

As a consequence of CC, water management will have to change in a way to become able to cope with changes in water quantities and water quality.

Need for reconsidering water management in terms of widening and deepening inclusive approaches for allocating water on a catchment basis, through openly agreed and fairly conducted procedures.

With this aim it is imperative that communication exists between the managers of river basins and scientists, allowing the application of scientific knowledge to water management itself.

IMPACTS - Navigation

Increased variability in climate conditions is likely to lead to more unstable navigability conditions on European waters and to increased costs of routine infrastructure maintenance (e.g. dredging) and renewal.

Low water levels reduce loading capacity and affect transport prices.

Increase in frequency of floods and storm surges could temporarily disrupt transport.

With reference to marine navigation sea level rise can cause coastal erosion, degradation of port structures and lowlands flooding.

IMPACTS - Hydropower and nuclear power generation

In general, the greatest vulnerability to climate in the hydropower industry for both planners and for operators is to drought, or any event which would threaten ensuring a long-term water supply.

Global figures on the evolution of the hydropower potential predict, by 2070, under a moderate scenario (A1B), that this potential will diminish by 6% at European scale.

Other energy infrastructures, such as power transmission lines, offshore drilling rigs and pipelines, might be damaged by flooding and more intense storm events.

With reference to nuclear power generation, some of the processed papers, also predict that the plants might be affected by increases in water temperature and water scarcity, due to their reliance on large volumes of water for cooling.

IMPACTS - Industrial production

Due to increased temperature, the demand for cooling water is at risk

In the big cities of North Europe, water demand has diminished in recent years, not only in terms of per capita consumption, but also of total consumption. This decrease occurred for multiple reasons:

- more environmentally friendly behaviour by consumers,
- development of technology with lower water demand,
- increased cost of water, which has provoked efforts by consumers, particularly big consumers/industry, to reduce their consumption.

IMPACTS - Tourism

Altered weather patterns induced by climate change could mean that Northern Europe becomes more attractive and reliable during the summer months, whilst the Mediterranean generally deteriorates in its appeal for tourists: the temperatures may become too hot, tropical diseases may become prevalent, there may be water shortages, the landscape may become arid and flash floods and forest fires may become more frequent.

In coastal and mountainous environments, where, tourism is vital for regional and local economies, climate change puts this at risk and could result in important market changes.

Seaside tourism, is likely to suffer damage from beach erosion and reduced water supply.

IMPACTS - Land use planning

The topic is closely related to the overall theme of "water management" and of "water supply". There is, in fact, growing recognition that climate change will increase the likelihood of flooding in some areas and of water shortages in other areas. Land use planning needs to respond to this.

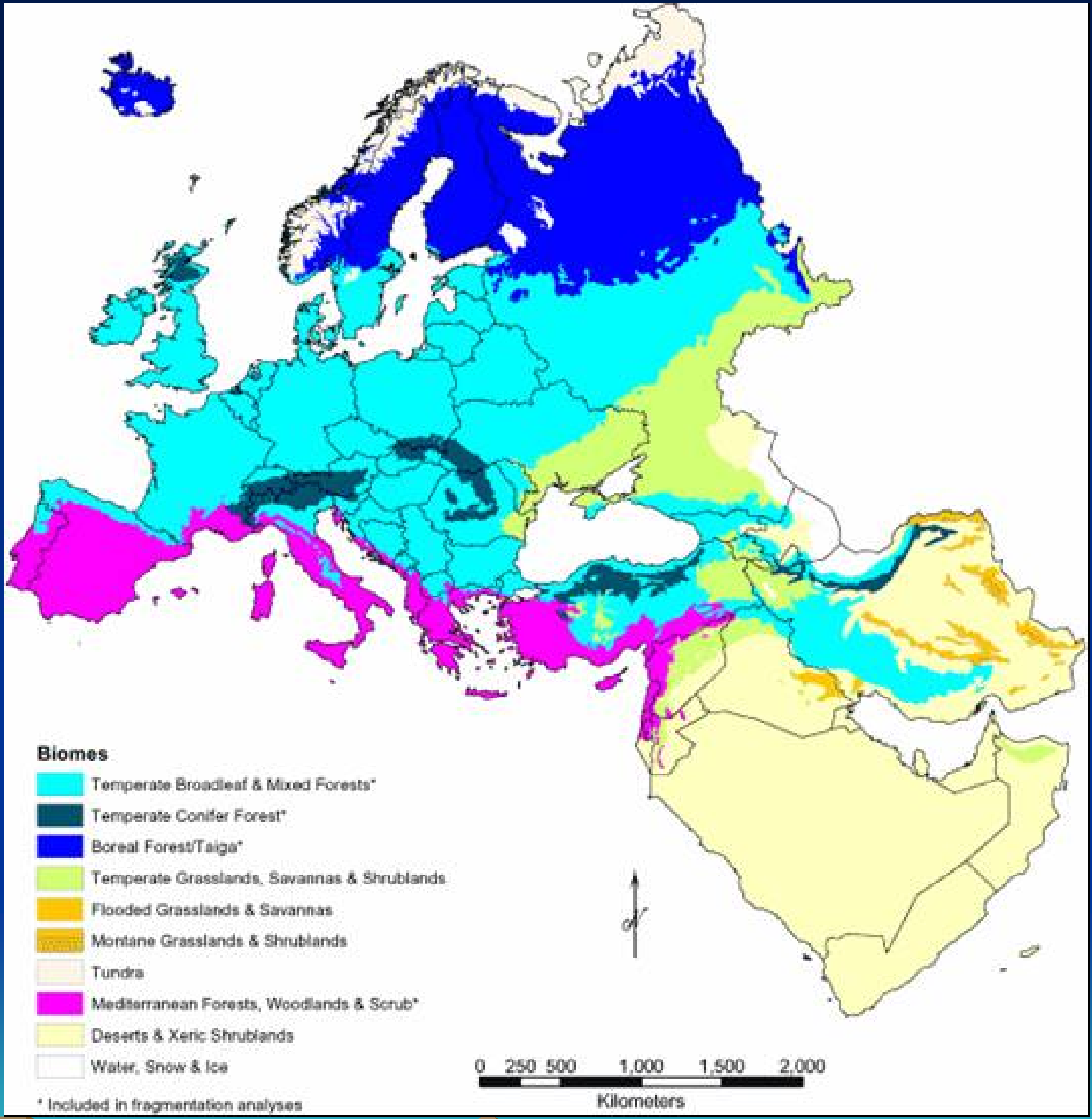
Unfortunately, economic growth and job/housing availability or demand for land use developments, are often seen as grounds more important than environmental concerns and are given precedence.

IMPACTS - Aquatic ecosystems

The number of papers on climate change impacts on aquatic ecosystems is huge, making the filtering of information for single biological elements not an easy task.

This is the reason why in the sub work package report, CC impacts on aquatic ecosystems are synthesized in form of tables. Each table is the result of an extensive publication query, carried out as first step in this project.

To draw these tables, the WFD eco-regions were assigned to their biomes as defined by Olson et al., 2001


Biomes
Temperate Broadleaf & Mixed Forests*
Temperate Conifer Forest*
Boreal Forest/Taiga*
Temperate Grasslands, Savannas & Shrublands
Flooded Grasslands & Savannas
Montane Grasslands & Shrublands
Tundra
Mediterranean Forests, Woodlands & Scrub*
Deserts & Xeric Shrublands
Water, Snow & Ice
* Included in fragmentation analyses
0 250 500 1,000 1,500 2,000
Kilometers

IMPACTS - Aquatic ecosystems (3)

Afterwards, with reference to each of these biomes, many of the WFD-quality elements (biological elements, hydro-morphological, chemical and physico-chemical elements supporting the biological elements), were considered. Successively, literature related to each of these WFD-quality elements was selected and certain contents were categorised: ▲ = increase, ▼ = decrease and R = replacement.

Aquatic ecosystems (4)

Biomes	Freshwater Ecoregions	Biological elements							
		phytoplankton		aquatic flora		invertebrate fauna		fish fauna	
		species composition	growth rate	species composition	growth rate	species composition	growth rate	species composition	growth rate
Mediterranean Forests	*1. Iberic-Macaronesian region*								
	Rivers		▲		▲	R	▲	R	
	Lakes		▲		▲		▲		
	Transitional waters								
	Coastal waters								
	3. Italy, Corsica and Malta								
	Rivers		▲		▲	R	▲	R	
	Lakes		▲		▲		▲		
	Transitional waters								
	Coastal waters								
	5. Dinaric western Balkan								
	Rivers		▲		▲	R	▲		
	Lakes		▲				▲		
	Transitional waters								
	Coastal waters								
	6. Hellenic wersfern Balkan								
	Rivers		▲		▲	R	▲	R	
	Lakes		▲				▲		
	Transitional waters								
	Coastal waters								
	7. Eastern Balkan								
	Rivers		▲		▲	R	▲		
	Lakes		▲				▲		
	Transitional waters								
	Coastal waters								

Table 1. Climate change impacts on biological quality elements (WFD) in the Mediterranean Forests Biome

IMPACTS - Terrestrial ecosystems

At global scale the evapotranspiration of forests is responsible for the majority of the world's freshwater budget (in the range of 60-80% from various literatures). Therefore climate change impact on forests and other terrestrial ecosystems could be the main driver of all water related problems.

CC, disturb the functioning of terrestrial ecosystems. Increased temperature and earlier snowmelt would likely enhance summer drought stress, especially if summer precipitation is also reduced.

This, in turn, influences the growth and yield of forests, affecting the composition of tree species and the generation rates of organic matter.

CC within a forest ecosystem, may also directly affect bird, amphibian, and reptile communities by concentrating populations and increasing their vulnerability to parasites and pathogens, as well as intra- and inter-specific competition.

IMPACTS - Terrestrial-aquatic ecotones

Ecotones are chacterised by specific physical and chemical characteristics, as well as by the occurrence of unique plant and animal communities with their associated biological processes. They are, besides, environments of exceptional diversity, but are also highly vulnerable to impacts and in particular to CC impacts.

The signals of ecological changes will be detectable first in ecotones.

Amphibian and fish reproduction fails more often in dry years and consequently organisms with poor dispersal abilities become extinct. Ground-nesting birds may be lost during floods.

In coastal ecotones sea level rise alters habitat conditions for present flora and fauna and opens a Pandora's box of migrating, alien and invasive species.

Conclusions

There is overall consensus that climate change affects water system dynamics through temperature changes, changes in precipitation patterns (e.g. more rainstorms) increase of evaporation (extended droughts) and decrease of water storage in snow packs, glaciers and the polar ice caps.

Apart from these changes of the climate directly affecting one or more water resources, it has to be always taken into account that to further complicate matter, there is the hydrological connectivity among rivers, lakes wetlands and groundwater, that is responsible for the reverberation of many of the impacts on any one of these types of water body upon one or more of the others.

Conclusions (2)

Huge number of papers have been published in the last decade on the likely consequences, the planet will be faced with, because of the ongoing and of the future changes of the climate.

A not so big, but still considerable, number of papers have been processed within WP2, and to draw meaningful conclusions from so many and assorted papers is not an easy task.

Besides, because it would be impossible, other than arbitrary, to make a choice among all the specific conclusions referred within all the processed papers, only some general conclusions are reported here.

Conclusions (3)

- Among these there is the strong sensitivity of water resources to even comparatively small changes in climatic characteristics obtained for many regions of the world. This seems particularly true for the arid zones of the Planet that already have difficulties with water supply and experience conflicts between different water users.

- It has also been reported that under all physiographic conditions, the values for water resources turn out to be more sensitive to changes in precipitation than in air temperature. This statement, in particular, allowed to assert that in the cases where the global warming is accompanied by a reduction in precipitation, water resources in the arid regions of the world will diminish drastically. Such regions occupy about 30% of Europe where it has been estimated that under the present changing climate there is a freshwater deficit which is increasing annually.

Conclusions (4)

- Reading some of the papers dealing with the consequences of the CC it might seem that the main adverse effects caused by climate change on the water supply would occur in arid and semi-arid areas only.

- Nevertheless it has to be mentioned that seasonal disruption might occur also in the water supplies of mountainous areas where, mainly because of increased temperature, the amount and duration of snow cover can be affected.

Conclusions (5)

- Predictions about hydrology are difficult in Europe because anthropogenic factors, such as changes in land-use patterns, the drainage conditions of rivers and an increasing proportion of impermeable areas, strongly influence the European hydrological cycle, mixing up their effects with those of the CC.

Conclusions (6)

- With reference to water use, it is forecasted that, in the next decades, agriculture will remain the largest water user in the Mediterranean countries, with more irrigation and warmer and drier growing seasons resulting from climate change. Abstraction for the electricity sector is projected to decrease dramatically over the next 30 years as a result of continuing substitution of once-through cooling by less water-intensive cooling tower systems; industrial water use is likely to stabilise or even decrease; in Eastern Europe, urban water supply may grow significantly.

Conclusions (7)

- In a worst-case scenario, the decrease of water availability that, , is expected to be particularly severe in the Mediterranean regions, might be also responsible for damage to animal species (reduction, degradation of fish and wildlife habitat, lack of feed and drinking water, migration and concentration, increased stress to endangered species) and to plant communities (loss of trees, increased number and severity of fires), with significant loss of biodiversity.

- Whichever the cause, the responsibility of climate change rests primarily with the developed and industrialised nations, while the costs will be borne most directly by the poor.

Conclusions (8)

- The magnitude of all the impacts will depend on the baseline conditions of the water supply system impacted, including the socio-economic situation of the area, that strongly conditions the vulnerability and the capacity to adapt of a system.

- There is, in fact, general agreement that development can, by its very nature, build adaptive capacity, helping poor countries to become less vulnerable to the impacts of climate change, by diversifying their economies and livelihoods, increasing access to markets, education and healthcare and building social and financial safety nets.

- This is the reason why it is suggested that development policies, rather than explicit adaptation strategies would be the most effective way to reduce the vulnerability to CC impacts.

Conclusions (9)

- There is also general agreement that, to cope with impacts of such a variety, magnitude and geographical extention, the measures have to be management, planning and political measures before that structural interventions. Only water resource managers, in fact, can respond to the combined effect of the climate change, of the population growth (and consequently of changes in demand) and of changes in technology, in economic, social and legislative conditions.

- With this reference, a need is acknowledged for reconsidering water management on a catchment basis, through openly agreed and fairly conducted procedures. These approaches have to take into consideration all classes of users, including the natural world. Besides, it has to be considered that, mainly where integrated water management systems exist, improved management may also protect water users from the effects of climate change at minimal costs.

Conclusions (10)

- Considering the transboundary extention of many of the CC impacts, some of the processed papers also conclude suggesting that integrating CC into foreign policies could greatly enhance the ability an willingness of nations and of the international community to meet the challenge of minimising the impact of the CC.

- Research is needed aimed at the reliable location of "hot spot" areas (special geographical areas containing either human populations or ecosystems highly vulnerable to impacts of climate change). The advantage is that the sparse resources of the society could be devoted, before all, to such limited areas.

Thanks for attention!

The past

The Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC) shows that the Earth's average surface temperature has risen by 0.76 °C since 1850. Most of the warming over the past 50 years is very likely to have been caused by emissions of carbon dioxide (CO_2) and other 'greenhouse gases' from human activities.

During the 20th century, most of Europe experienced increases in average annual surface temperature (average increase over the continent 0.8°C), with stronger warming over most regions in winter than in summer. The 1990s were the warmest according to instrumental records.

The future

There are numerous indications that the climate change (mainly precipitation and temperature change) will assume different charcteristics in different parts of Europe.

The most recent climate modelling shows an increase in annual temperature of 0.1 to 0.4°C over the 21st century based on a range of scenarios and models (Figure left).

The models show a widespread increase in precipitation in the north, small decreases in the south, and small or ambiguous changes in central Europe (Figure right). It is likely that the seasonality of precipitation will change and the frequency of intense precipitation events will increase, especially in winter.

The future

Because much of the solar energy received by the Earth is used to drive the hydrological cycle, higher levels of solar energy trapped in the atmosphere will lead to an intensification of this cycle, resulting in changes in the alteration of the amount and distribution of precipitation.

These changes will result in increased floods and drought which, in turn will be responsible for altered runoff regimens, river flows and river basin discharges that. On the whole, will have significant impacts on the availability of freshwater.

Some examples of the forecasted climate changes in extreme synthesis

- Annual average runoff is projected to increase in northern Europe (north of 47°N) by approximately 5 to 15% up to the 2020s and 9 to 22% up to the 2070s.

- Meanwhile, in southern Europe (south of 47°N), runoff decreases by 0 to 23% up to the 2020s and by 6 to 36% up to the 2070s (for the same set of assumptions).

According SRES A2 and B2 scenarios and climate scenarios from two different climate models (Alcamo et al., 2007).

Some examples of the forecasted climate changes in extreme synthesis (2)

- Groundwater recharge is likely to be reduced in central and eastern Europe (Eitzinger et al., 2003), with a larger reduction in valleys (Krüger et al., 2002) and lowlands (e.g., in the Hungarian steppes) (Somlyódy, 2002).
- Summer low flow may decrease by up to 50% in central Europe (Eckhardt and Ulbrich, 2003), and by up to 80% in some rivers in southern Europe (Santos et al., 2002).
- It is likely that glacier retreat will initially enhance summer flow in the rivers of the Alps; however, as glaciers shrink, summer flow is likely to be significantly reduced (Hock et al., 2005), by up to 50% (Zierl and Bugmann, 2005).

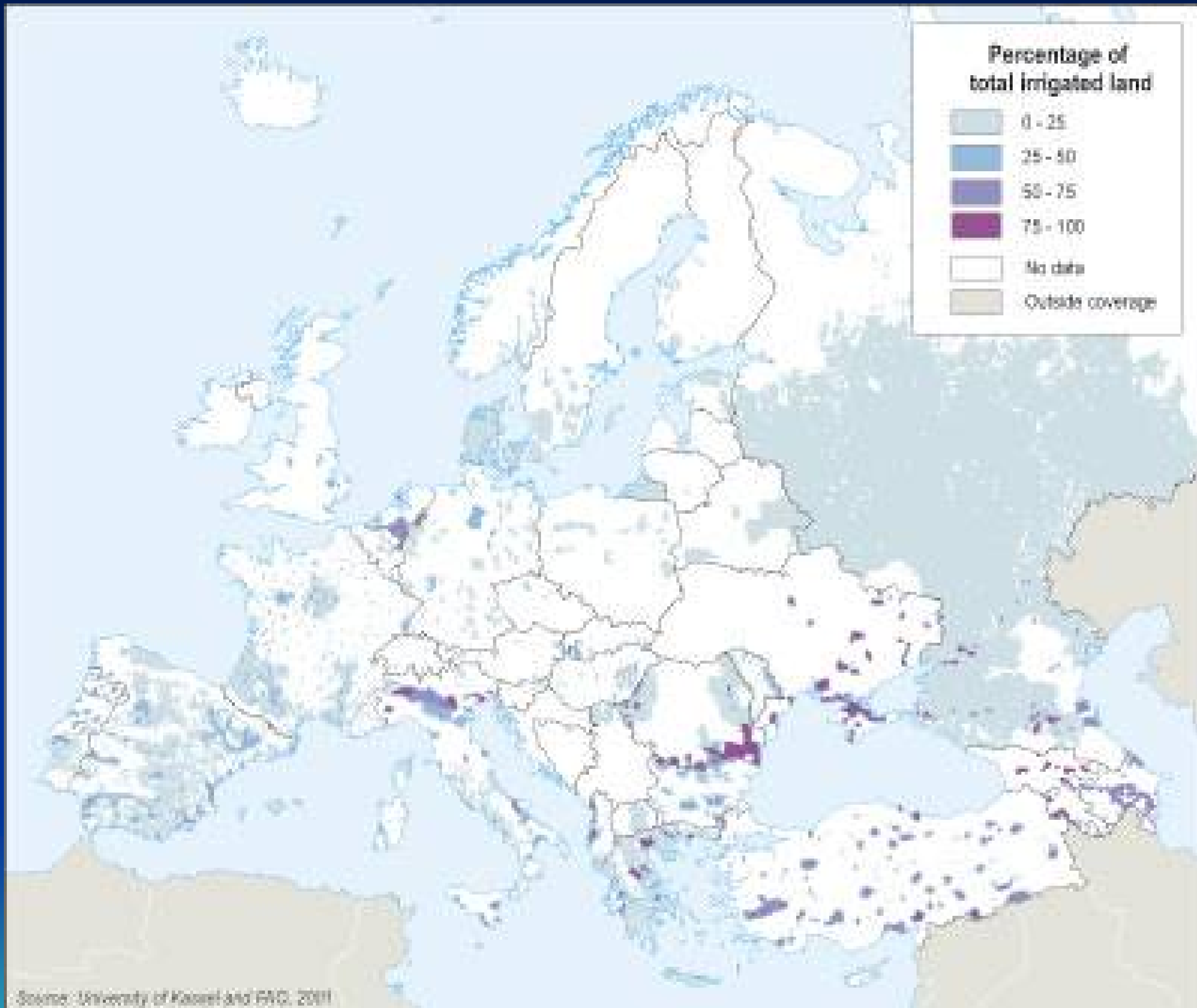
Model simulations

The frequency and intensity of convective storms leading to extreme weather events cannot be forecasted accurately with current simulations. The sensitivity of change in water runoff to the change in temperature is significant therefore the accuracy of models should be increased, especially, if adaptation strategy and planning would be based on model projections.

Extremely precise predictions generally suffer from rather high uncertainty degerees.

Only with a deep consciousness of these limits, model use can produce the best possible results.

PERCENTAGE OF TOTAL IRRIGATED LAND



Southern European countries have the largest area of irrigated land in Europe, and use around three times more water per unit of irrigated land than other parts of Europe.

Water use

On average, 42% of total water abstraction in Europe is used for agriculture, 23% for industry, 18% for urban use and 18% for energy production.

Nevertheless it has to be taken into account that sectoral water use changes considerably across Europe (Fig.). Agriculture, in particular, accounts for 50–70% of total water abstraction in south-western European countries, while cooling for electricity production is the dominant use in Central European countries. It is likely that, in case of water scarcity, the most impacted sectors, will be those that use the greatest water quantities; these are also the sectors which will benefit most from greater water availability.

Number of dry months/year