Water Management in a Changing Environment

Strategies against Water Scarcity in the Alps

Project Outcomes and Recommendations

ALP-WATER-SCARCE OCT. 2008 – OCT. 2011

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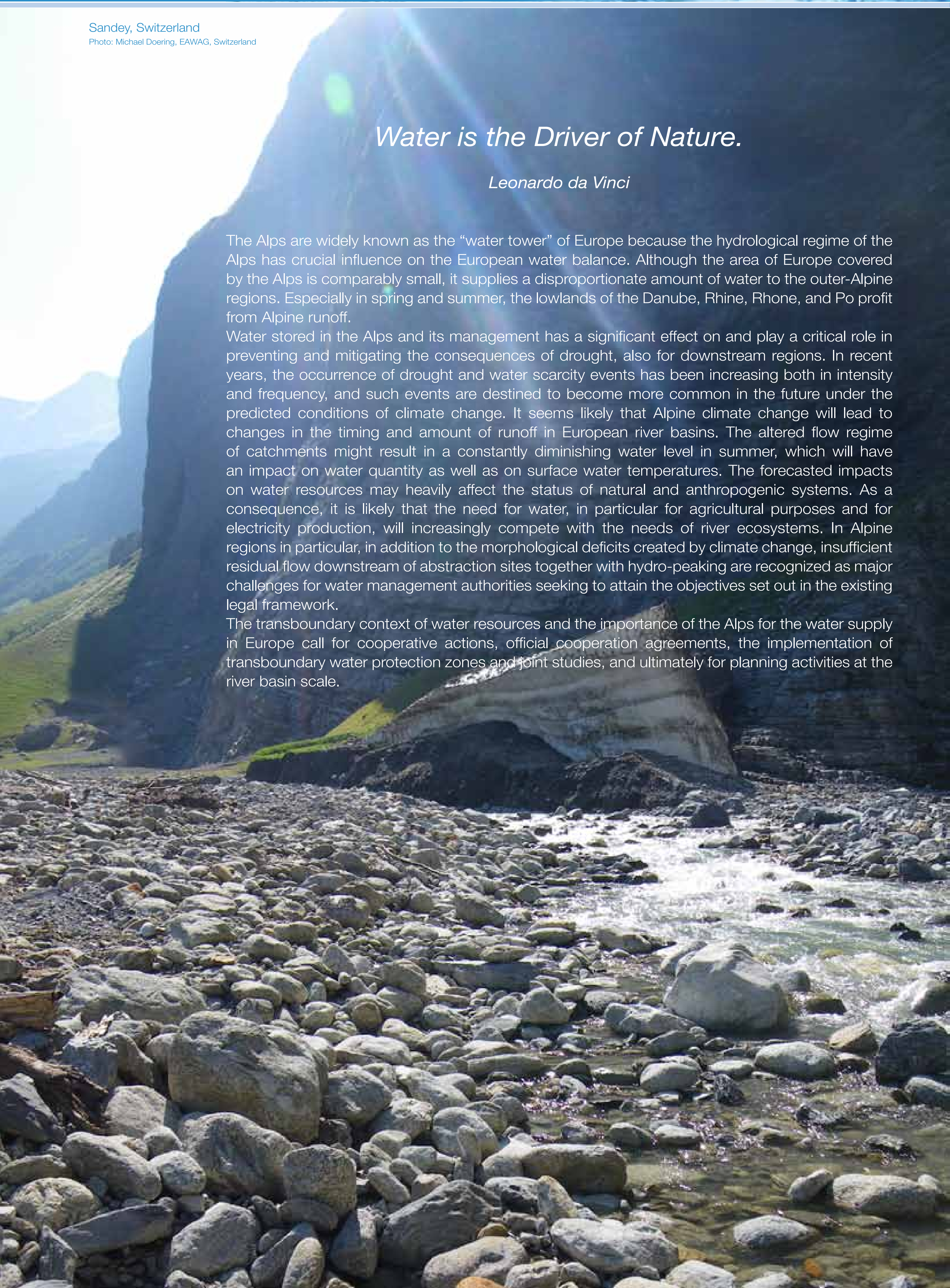


Sandey, Switzerland
Photo: Michael Doering, EAWAG, Switzerland

Water is the Driver of Nature.

Leonardo da Vinci

The Alps are widely known as the “water tower” of Europe because the hydrological regime of the Alps has crucial influence on the European water balance. Although the area of Europe covered by the Alps is comparably small, it supplies a disproportionate amount of water to the outer-Alpine regions. Especially in spring and summer, the lowlands of the Danube, Rhine, Rhone, and Po profit from Alpine runoff.

Water stored in the Alps and its management has a significant effect on and play a critical role in preventing and mitigating the consequences of drought, also for downstream regions. In recent years, the occurrence of drought and water scarcity events has been increasing both in intensity and frequency, and such events are destined to become more common in the future under the predicted conditions of climate change. It seems likely that Alpine climate change will lead to changes in the timing and amount of runoff in European river basins. The altered flow regime of catchments might result in a constantly diminishing water level in summer, which will have an impact on water quantity as well as on surface water temperatures. The forecasted impacts on water resources may heavily affect the status of natural and anthropogenic systems. As a consequence, it is likely that the need for water, in particular for agricultural purposes and for electricity production, will increasingly compete with the needs of river ecosystems. In Alpine regions in particular, in addition to the morphological deficits created by climate change, insufficient residual flow downstream of abstraction sites together with hydro-peaking are recognized as major challenges for water management authorities seeking to attain the objectives set out in the existing legal framework.

The transboundary context of water resources and the importance of the Alps for the water supply in Europe call for cooperative actions, official cooperation agreements, the implementation of transboundary water protection zones and joint studies, and ultimately for planning activities at the river basin scale.

Next to blood relationships, come water relationships.

Stanley Crawford, Mayordomo

Reservoirs and lakes have an important function as balancing elements in the water cycle; now more than ever, in the light of climate change, their function of providing water for downstream areas during dry periods could become increasingly more important in the light of climate change. However, it should be noted that the potential of regulating and topping up runoff for downstream areas is limited by restricted lake storage capacities and the interests of parties on the shores of the lakes themselves. Thus, expectations from downstream areas should take this into account; water managers should regard the potential use of upstream lakes as only an attenuating factor for satisfying their demands and should look for solutions in terms of the level of demand.

Also on a local basis, temporal water stress due to rather recent increases in water usage (e.g., snowmaking) can occur. Artificial snowmaking may cause user conflicts between operators of snowmaking facilities, households, and other water demand stakeholders. The retention and storage of water in ponds can contribute towards the mitigation of such effects. However, this type of infrastructure entails further construction in fragile environments; therefore, during the authorization process, due consideration must be given to environmental concerns.

A number of case studies have demonstrated that drought management is of the utmost importance for agriculture and irrigation. Agricultural production is likely to be the sector most sensitive to climate fluctuations, as both climate change and climate variability have direct impact on the quantity and quality of the sector's output. The role of early warning and weather monitoring systems (bother for periods of favorable climatic variation and, more importantly, for adverse changes) should therefore be emphasized.

In these circumstances, drafting effective emergency plans and long-term management strategies to prevent and mitigate drought risks is becoming a priority. On the basis of future scenarios of the evolution of water resources and estimated future changes in water demand from the most important water users, this task could be achieved by reducing demand, but also by the diversification and utilization of additional water resources.

Various water management instruments that could help to prevent or resolve potential conflicts include a legislative framework, bi- and multilateral agreements, planning instruments, conferences, and scientific approaches to facilitate the characterization and solution of the problems. Political representatives and all stakeholders in general must be involved in the ongoing processes of water management using the instruments in place.

All parties to the Alpine Convention have agreed that the connection between water scarcity, droughts, climate change, and the associated adaptation strategies, including the aspects already dealt with in the EC Green Paper on adaptation to climate change in Europe, should be integrated into the implementation of the Water Framework Directive (WFD) and its River Basin Management Plans to the greatest extent possible. Water management adaptation and mitigation measures in terms of climate change were established within the framework of the Climate Action Plan of the Alpine Convention. At the XI Alpine Conference in Brdo, Slovenia, in March 2011, the ministers of the Alpine Convention adopted the "Common guidelines for the use of small hydropower in the alpine region", which recommends consideration of the ecological potential of a proposed site and time limits for concessions or licenses, making them as short as possible without compromising the investment. The underlying reasons for this are predicted climate change and changes in water availability.

The handbook for water managers of the Alp-Water-Scarce project is a valuable contribution towards the enhancement of effective water management tools at the local level, precisely where decisions must be taken. Guidance and input to ensure constructive long-term processes for planning and mitigation are necessary in order to ensure integrated water resources management relating to the use of water, the protection of water, and protection from risks to the water supply.

Regula Imhof
Vice-Secretary General of the Alpine Convention[1]

1 This foreword represents the personal opinion of the author and does not necessarily reflect the point of view of the permanent secretariat.

Introduction

The role of mountains in providing indispensible water resources for municipal and industrial water supply, irrigation, hydropower production, and other environmental services is well-known and unquestioned (e.g., Barnett et al. 2005; EEA 2009; Viviroli 2003, 2007).
Furthermore, several studies have also underlined the sensitivity and vulnerability of these mountain ecosystems to the impacts of climate change (Beniston 1994; Diaz et al. 1997; COM 2009).
In Europe, in particular the Alps, with their seemingly vast water resources, are of immeasurable importance for the economic and cultural development of not only the Alpine Arc, but also of the lowlands and major urban areas far away. Although it seems that drought events or water scarcity problems in the Alps have only occurred over short periods of time and in small, distinct areas (PSAC 2009), certain events in the past have raised awareness and can be seen as the triggers for initiatives to address these hazards.
In 1921, at a time when climate change was not at all a major issue, the Alps faced a period of drought that caused international concern (New York Times 1921a). Rifts in glaciers and a lack of water for cattle in the Alpine pastures in Switzerland were reported. As a result of this natural crisis, the Swiss Government appointed a special commission of experts "to consider what measures must be […] taken to safeguard the country's water supply for domestic use and for electrical power in case of there being another such drought" (New York Times 1921b).
More recently, the severe droughts that affected parts of Europe in 2003 also had a significant impact on the water resources of the water-rich Alpine regions. The creation of the European Drought Centre in 2005 can be seen as one of the results of this experience; others include communications by the Commission to the European Parliament and the European Council (EC 2007) and the establishment of several regional and local initiatives (e.g., the Drought Committee in France). Efforts to deal with the topic of water scarcity and droughts have been made at the legislative level; in addition, at the scientific level, many studies (e.g., ACQWA: http://www.unige.ch/climate/Projects/ACQWA.html; GlowaDanube: http://www.glowa-danube.de/de/home/home.php; KLIWA: http://www.kliwa.de/; MontanAqua: http://www.montanaqua.ch/) have been carried out to assess the effects of climate change and its impacts on the water resources of the Alps, resources that are also in part at risk due to increases in anthropogenic water abstraction.
For examination of the evolution of the climate in the Alps in the recent past, the HISTALP database's homogenized long-term series of climatological data provides valuable information. In

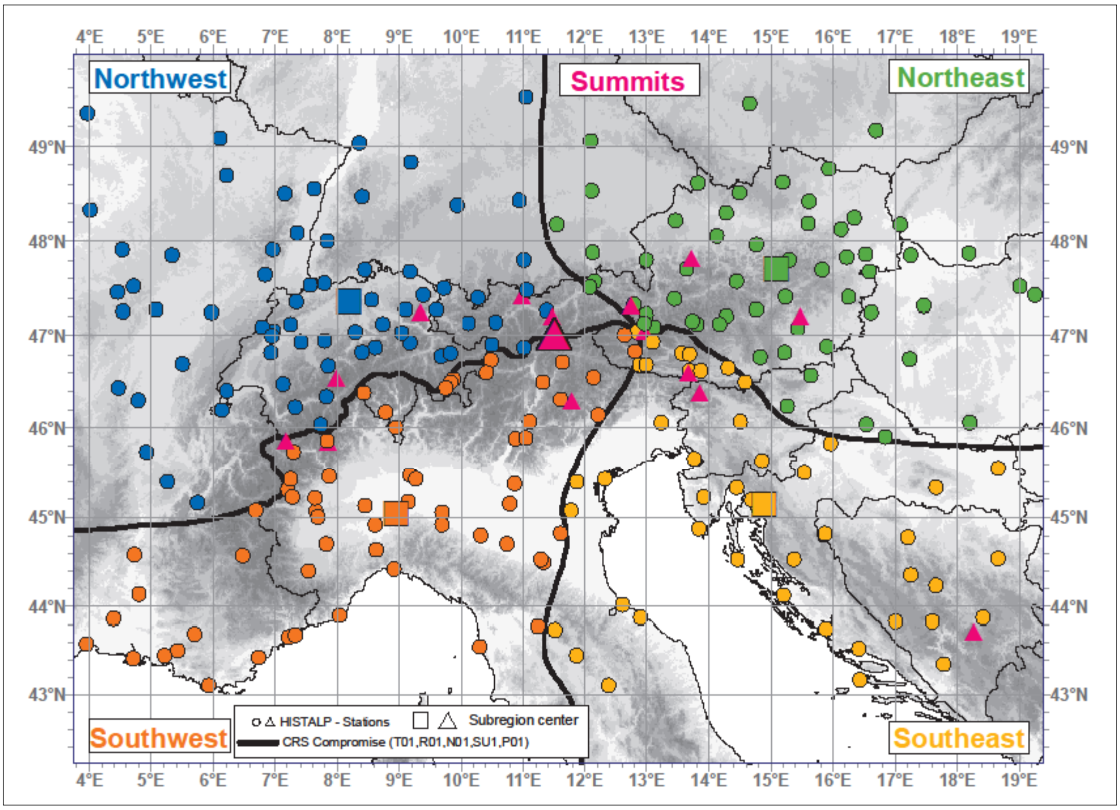


FIGURE 1: The current HISTALP network with approximately 200 stations (Böhm et al. 2009).

this dataset, the so-called “Greater Alpine Region” (GAR) is divided into four climatologically different sub-regions (CSR), as shown in Figure 1 (Auer et al. 2007; www.zamg.ac.at/histalp; Böhm et al. 2009).

For the Alpine region, temperature anomalies are more pronounced in comparison to global variations (Figure 2). The warming trend that started at the end of the 19th century has increased significantly since the early 1980s. Figure 3 shows that the temperature anomalies compared to those of the 20th-century mean are very similar for all Alpine sub-regions.

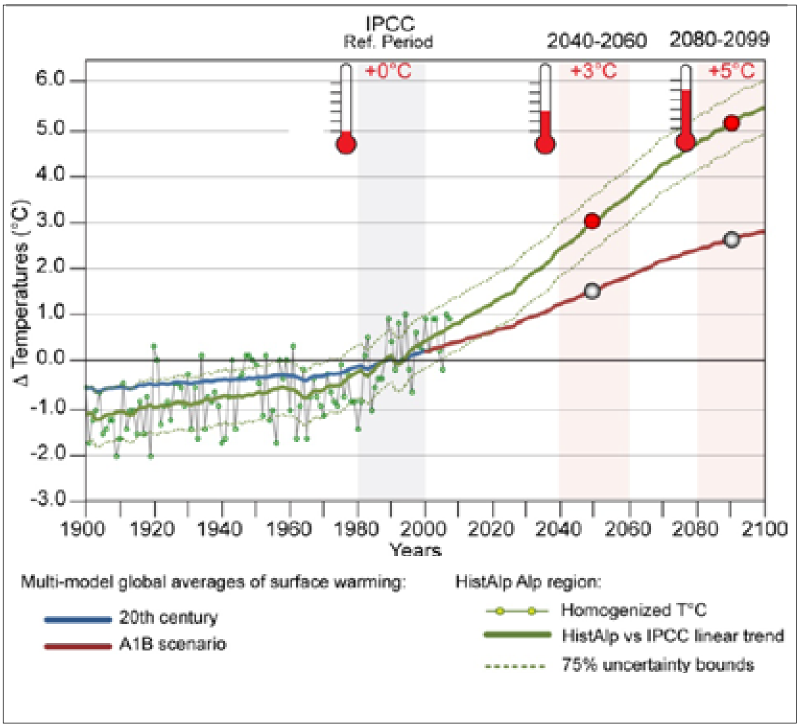


FIGURE 2:
Global and Alpine temperature change (Saulnier et al. 2011).

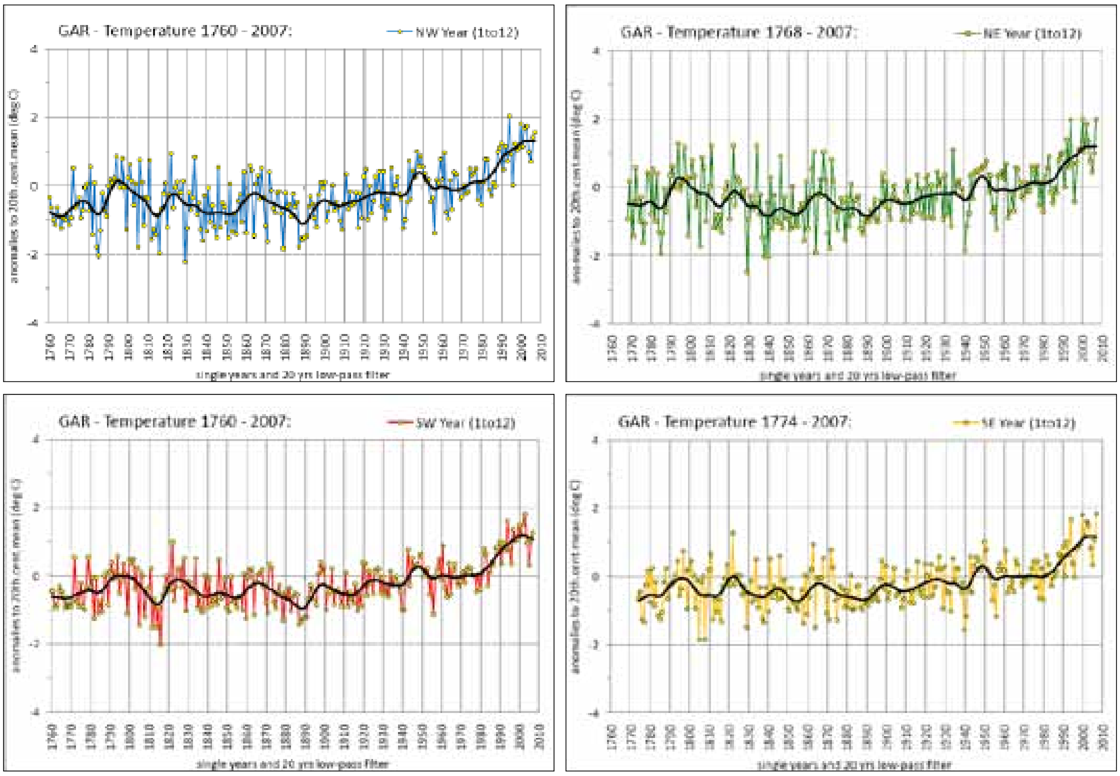
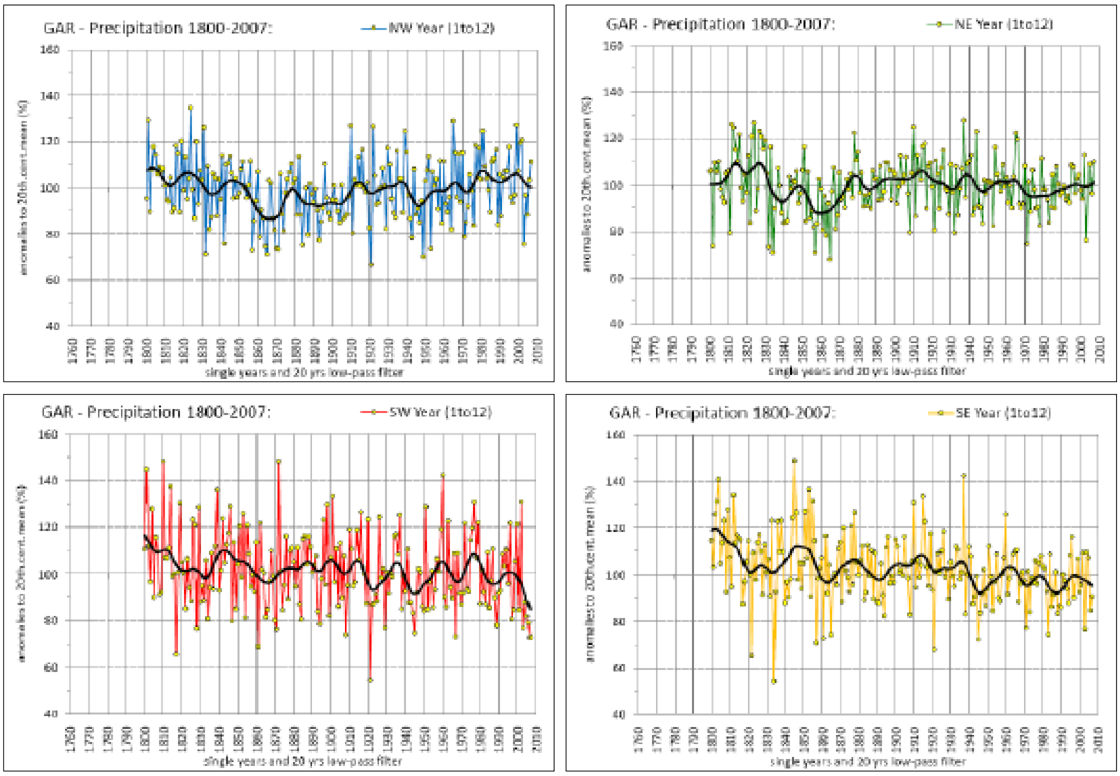


FIGURE 3:
Regionally averaged time series of the four sub-regions’ temperature stations. The charts show the anomalies to the 20th-century mean (www.zamg.ac.at/histalp).

The long-term series for precipitation shows more regional differentiation (Figure 4) and higher inter-annual variability, which is why precipitation trends are not as significant as in the case of air temperature. For the northwest Alpine region, a slight increase in precipitation can be observed with low significance. For the northeast region, no trend can be detected. In the southeast and southwest Alpine regions, a clear negative trend of annual precipitation can be observed (more significant in the southeast).

FIGURE 4: **Regionally averaged time series of the four sub-regions' precipitation stations. The charts show the anomalies to the 20th-century mean (www.zamg.ac.at/histalp).**



Regarding future changes in the Alpine climate, the results of regional climate multi-model simulations performed in the course of the EU-FP6 project ENSEMBLES (http://www.ensembles-eu.org/) show the following trend in scenarios up to the year 2050:

- A temperature change of as much as +1.5 °C by 2050 (0.25 °C per decade). All models show a positive trend (robust signal).
- Precipitation: High regional and seasonal differences; the Alps represent a transition zone, where no robust conclusions are possible. The model simulations indicate a trend of more precipitation in winter, which is contradictory to the historical trends derived from HISTALP.

In any case, it is evident that an increase in air temperature coupled with an increase in evapotranspiration and less precipitation in the form of snow (leading to fewer days with snow cover, at least in altitudes at which the additional precipitation does not fall as snow (Strasser et al. 2008)), regionally combined with reduced precipitation, will have an important impact on the water balance of the Alps: changes in runoff, groundwater resources, low-flow conditions, and evapotranspiration will occur (Beniston 2003; Burlando & Rosso 2002) that may increase the risk of drought or water scarcity periods (Mauser et al. 2008).

Although experts agree on the fact that water scarcity and drought will remain a local problem in the Alps, both increasing water abstraction and the impacts of climate change will increase the need for adaptation measures. Furthermore, potential user conflicts must also be taken into account. Several studies (e.g., BMBFW 2011; EEA 2009) underscore the need to adapt current water management practices in order to avoid periods of water scarcity.

The implementation and operational application of early warning systems, coupled with efficient crisis management through legislative measures, can contribute to the prevention of water shortages in the short-term. However, long-term measures are also needed in order to foster sustainable water management in the future.

In October 2008, a consortium of 17 project partners from five European countries began to work on the Alpine Space project "Alp-Water-Scarce" to provide possible solutions to prevent periods of water scarcity and to develop and promote an integrated and sustainable approach to water management.

The measures recommended in this handbook cannot be seen as solutions for the Alps per se, since the different national and European (e.g., Water Framework Directive) legislative frameworks of water governance must be taken into account. However, these recommendations are based on sound investigations at the different Pilot Sites of Alp-Water-Scarce. In the first sections of this handbook, a definition of 'water scarcity' and different stakeholder perspectives on the term are presented. An overview of water scarcity problems in different sectors and the legal aspects of water governance at different levels are then provided. In the last section, recommendations to address water scarcity are proposed.

1 Water Management Strategies against Water Scarcity in the Alps – the "Alp-Water-Scarce" Project

The initial project idea of Alp-Water-Scarce was presented in St. Johann im Pongau, Austria, at the Alpine Space programme kick-off conference in the summer of 2007. The idea to develop an early warning system to guard against water scarcity and transnational concepts for water management was jointly conceived by Joanneum Research and the Province of Carinthia, Austria. The need for such an early warning system was stressed by a study in the Sattnitz area in Carinthia, Austria, where groundwater recharge has significantly decreased (by approximately 25%) over the past 100 years (Harum et al. 2008). In October 2008, the ETC Alpine Space project "Alp-Water-Scarce" was launched with the objective of developing a transnational approach to confront the problem of water scarcity. The project was implemented by a strong consortium that gathered the expertise and experience of different institutions and organisations from various disciplines of applied research and water management, supported by a large number of project observers and an external advisory board.

The necessarily transnational nature of Alp-Water-Scarce is affirmed by the fact that in addition to their role as "the water towers of Europe", the Alps are interconnected with many surface and subsurface transnational water bodies.

Based on the view that detailed regional studies are vital for the effective management of mountain water resources (Viviroli et al. 2010), the Alp-Water-Scarce consortium selected 22 so-called Pilot or Test Sites situated at locations across the Alpine Arc. Actual and emerging problems of water scarcity resulting from climate change as well as from increasing water abstraction and other anthropogenic impacts such as pollution were investigated. Due to the variety of hydro-climatic situations and anthropogenic impacts (hydropower generation, drinking water supply, irrigation, artificial snow production, etc.), the institutions faced very different challenges related to water resources management.

In addition to human influence and climate change, ecological aspects (optimal ecological discharge) and legislative frameworks (national water governance and European frameworks) were also considered. In response to the urgent need to improve the knowledge exchange between water managers and researchers highlighted by Viviroli et al. (2010), a "Stakeholder Interaction Forum" was established in order to include stakeholders from different levels in the project from the very beginning.

The main aim of Alp-Water-Scarce can be summarised as "to develop strategies and concepts for sustainable water management in the future".

To achieve this aim, the following actions were undertaken:	
1.	Characterization and monitoring of the water systems in the Pilot Sites in order to assess their vulnerability to hydro-climatological pressures and shifts in water balance components. Past, present, and future water usages in these catchments were identified and quantified.
2.	Where hydrological and meteorological data were available, modelling activities were undertaken. Historical hydro-meteorological data were used to create hydrological scenarios.
3.	In order to account for ecological aspects in water management during periods of water scarcity, studies to define the optimal ecological discharge were performed. The development of drought indicators applicable for the various Alpine regions was initiated.
4.	Project observers and stakeholder from various levels, including water managers, public authorities, and other organizations were involved and informed at all phases of the project by means of workshops and newsletters, in order to get an overview of how they perceived water scarcity in the past, what they are experiencing at present, and what issues they think may arise in the future.
5.	The legislative framework of water scarcity management in Austria, France, Italy, Slovenia, and Switzerland, as well as at the European level, was investigated to identify aspects of water management strategies currently practiced or to be developed in the future to overcome hurdles for transalpine water resources management.
6.	All of the above-mentioned actions contributed to the development and operation of early warning systems adapted to specific challenges at the local level: the Arly catchment (France), the entire Province of Carinthia (Austria), and the Piave catchment (Italy). In addition, an early warning system for agriculture in Slovenia was developed and installed, providing irrigation advice for farmers on a weekly basis via a website. The theoretical concept common to all these alert systems will provide a guideline for how to transfer them to other regions in the Alps.
7.	The recommendations presented in this handbook are based on the experience and the results obtained from work at the Alp-Water-Scarce Pilot Sites. They are intended as transnational concepts for improving water management for Alpine regions to confront future water scarcity problems.
8.	Finally, all these working efforts have resulted in a series of recommendations for the Alpine Convention.

The challenge of Alp-Water-Scarce, but also its strength, was to start from the different concerns of the various partners at the Pilot Sites with regard to water management issues. The ultimate goal was to translate the results of the activities undertaken into a sound set of recommendations. Based on the huge number of topics studied, this handbook provides possible solutions for a variety of upcoming questions.

2 Definition and Perception of Water Scarcity

Although it seems difficult to separate the terms “water scarcity” and “drought”, the Alp-Water-Scarce consortium has agreed upon the definitions provided in Table 1, which are based on documents provided by the European Commission (EC 2007) and the European Drought Centre (http://www.geo.uio.no/edc/). Furthermore, it should be noted that frequently the term “water scarcity” only takes into account the quantity of water resources, although pollution (e.g., eutrophication) also has an impact on the amount of usable water, and a decrease in water availability results in an increase in pollution. In addition to the overview provided in Table 1, it might be of use to consider the detailed definition of the term “drought” provided by the National Drought Mitigation Center of the University of Nebraska-Lincoln, US (http://drought.unl.edu/whatis/concept.htm):

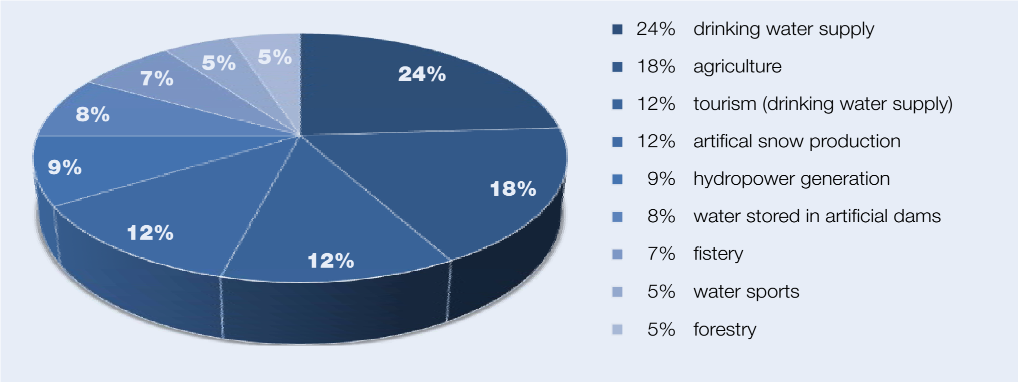
Meteorological Drought is usually defined on the basis of the degree of dryness (in comparison to some “normal” or average amount) and the duration of the dry period. Definitions of meteorological drought must be considered as region-specific, since the atmospheric conditions that result in deficiencies in precipitation are highly variable from region to region.
Agricultural Drought links various characteristics of meteorological (or hydrological) drought to agricultural impacts, focusing on precipitation shortages, differences between actual and potential evapotranspiration, soil water deficits, reduced groundwater or reservoir levels, and so forth. Plant water demand depends on prevailing weather conditions, biological characteristics of the specific plant, its stage of growth, and the physical and biological properties of the soil.
Hydrological Drought is associated with the effects of periods of precipitation shortfalls (including snowfall) on surface or subsurface water supply (i.e., streamflow, reservoir and lake levels, and groundwater). The frequency and severity of hydrological drought is often defined on a watershed or river basin scale. Although all droughts originate with a deficiency in precipitation, hydrologists are more concerned with how this deficiency plays out throughout the hydrologic system. Hydrological droughts are usually out of phase with or lag behind the occurrence of meteorological and agricultural droughts. It takes longer for precipitation deficiencies to show up in components of the hydrological system, such as soil moisture, streamflow, and groundwater and reservoir levels.
Socio-economic Drought associates the supply and demand of some economic good with elements of meteorological, hydrological, and agricultural drought. It differs from the aforementioned types of drought in that its occurrence depends on the time and space processes of supply and demand to identify or classify droughts.

TABLE 1: Difference between water scarcity and drought.

	Water scarcity	Drought
Length	Long-term water imbalance	Temporary decrease of water availability
Driving forces	Natural (low precipitation) Human-driven (overexploitation, pollution)	Natural, related to seasons
Characteristics of the affected areas	Low water availability and/ or high levels of water consumption	Unfavourable meteorological conditions: low precipitation and/or high temperatures
Preventing measures	Long-term measures and short-term crisis management	Long-term measures and short-term crisis management

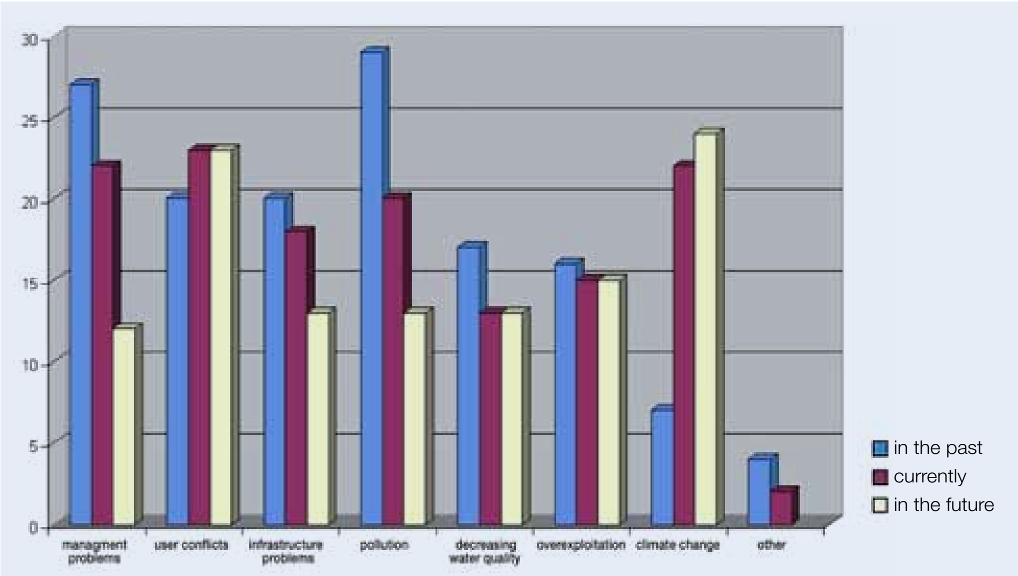
In addition to these definitions, relevant information on the past, present, and future perceptions of stakeholders regarding regional water scarcity was collected. The analysis of 84 stakeholder questionnaires collected at the Pilot Sites of Alp-Water-Scarce identified the complexity of problems resulting from water scarcity at different levels. 56% of the interviewees represented public administrations. On a transalpine level, 82% of the stakeholders indicated that they had been affected by problems related to water scarcity in the past, whereas only 66% indicated that they were affected by this phenomenon at present. Figure 5 gives an overview of the sectors presumed to be affected by water scarcity: drinking water supply (24%) and agriculture (18%) are expected to suffer the most, followed by artificial snow making and tourism (12%) and hydropower generation (9%).

FIGURE 5:
Sectors influenced by water scarcity in the Alps.



Regarding reasons for water scarcity, the interviewed stakeholders considered that pollution and management problems had been fundamental in the past; in the present, they believed that more difficulties arise from usage conflicts and climate change. In the future, climate change is perceived to be the most probable cause of increasing water scarcity (Figure 6).

FIGURE 6:
Main causes of water scarcity in the past, the present, and the future.



When asked about the frequency of water scarcity, the interviewees indicated that such events are characterised by strong seasonality.
Although it is perceived that climate change will increase the frequency of water scarcity in the future (84%), only 32% of the interviewed stakeholders knew about existing regional plans to adapt water management or their impacts.
Focusing on the countries that participated in the survey (Austria, France, Italy, Slovenia, and Switzerland), some striking national differences can be observed in the perception and the importance of the different causes of water scarcity as well as the sectors seen as most affected. Austrian stakeholders attached great importance to "infrastructure problems" connected with water scarcity problems in the past, the present, and the future; in France, in contrast, climate change is – especially for the future – perceived as the driving force for water scarcity. In Slovenia, pollution is still of major concern. In Italy, past "over-exploitation" of water resources is one reason given for water scarcity.
Regarding the sectors affected by water scarcity, drinking water supply is seen as the most vulnerable sector in Austria, whereas in Italy the most affected sectors are thought to be agriculture and hydroelectric power generation.

3 Challenges of Water Scarcity in the Alp-Water-Scarce Pilot Sites

The Pilot Sites of Alp-Water-Scarce are not regularly distributed along the 1200 km of the Alpine Arch; rather, they are mostly situated in the southern parts of the Alps, which is also reflected by the structure of the project partnership and thus by the importance of the topic for these areas and the participating institutions. Figure 7 shows the 22 Pilot Sites that were chosen for the project. In addition, Table 2 provides an overview of the main challenges these 22 sites are facing. Sustainable drinking water supply is certainly the most important issue, followed by agriculture and hydropower generation. However, the interaction between tourism (no differentiation was made between summer and winter tourism) and water resources is also an issue in some Pilot Sites, as are tunnel construction and thermalism.

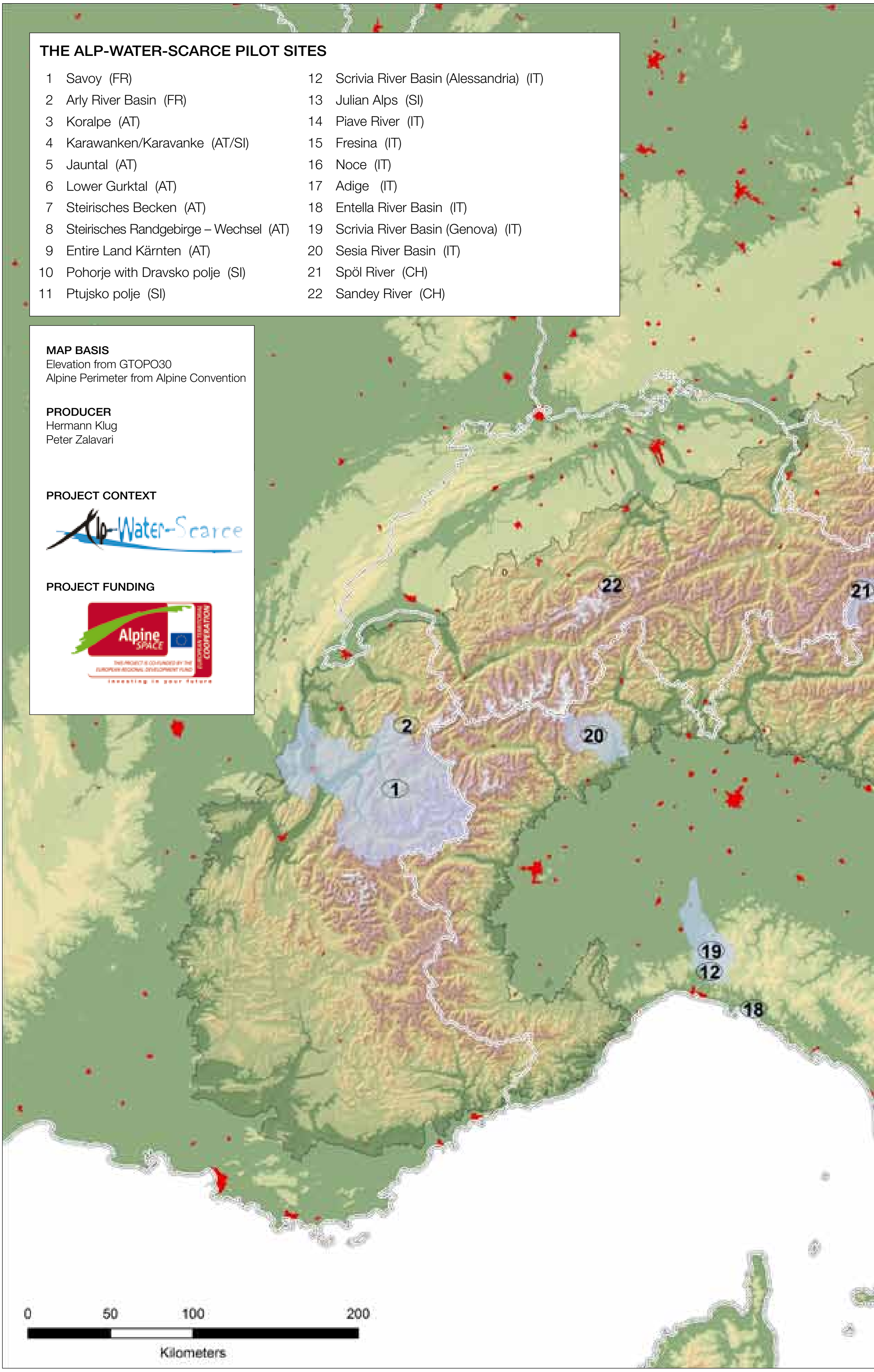
TABLE 2: Main concerns and their importance at the Alp-Water-Scarce Pilot Sites.

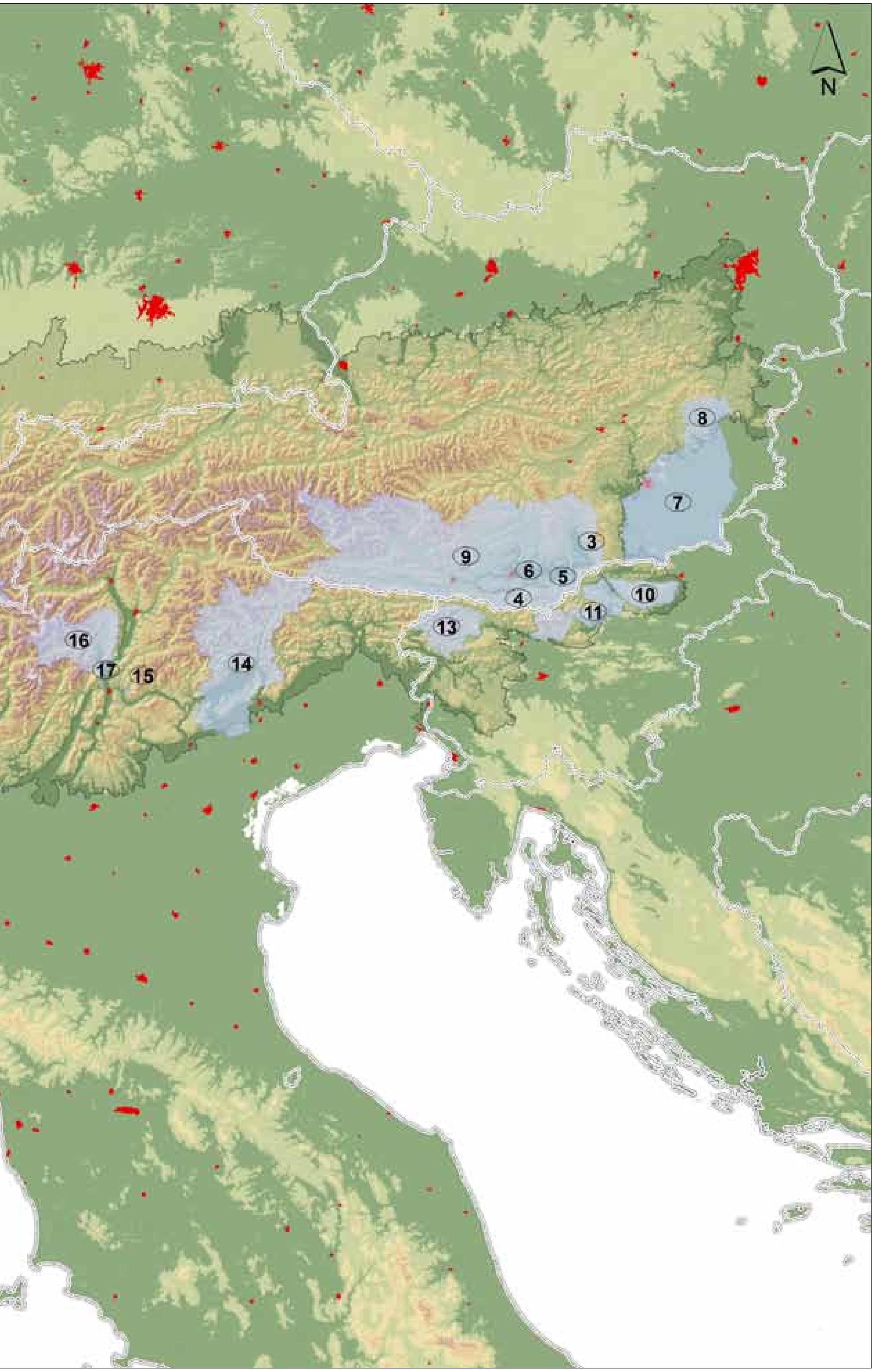
Data from Pilot Sites 15 "Fersina" and 17 "Adige" are missing since only experiments were performed at these Sites. No other data were collected.

ID	Site	Drinking Water Supply	Agriculture	Hydropower generation	Tourism	Tunnel construction	Thermalism
1	Savoy	Medium	Medium	Medium	Medium	Medium	Low
2	Arly River Basin	High	Medium	Low	Medium	Low	Low
3	Koralpe	Medium	Low	Medium	Low	High	Low
4	Karawanken/Karavanke	High	Low	Low	Medium	High	Low
5	Jauntal	Medium	Medium	Low	Low	Low	Low
6	Lower Gurktal	High	High	Low	Low	Low	Low
7	Steirisches Becken	High	High	Low	Medium	Low	Medium
8	Steirisches Randgebirge – Wechsel	Medium	Low	Low	Low	Low	Low
9	Entire Land Kärnten	Medium	Medium	Medium	Medium	Low	Low
10	Pohorje with Dravsko polje	Medium	High	High	Low	Low	Low
11	Ptujsko polje	High	High	High	Low	Low	Low
12	Scrivia River Basin (Alessandria)	Medium	Medium	Low	High	Low	Low
13	Julian Alps	High	Low	Medium	High	Medium	Low
14	Piave River	Medium	High	High	Medium	Low	Low
16	Noce	High	High	High	High	Low	Low
18	Entella River Basin	High	Medium	Low	High	Low	Low
19	Scrivia River Basin (Genova)	High	Medium	Low	Medium	Low	Low
20	Sesia River Basin	Low	Low	High	Low	Low	Low
21	Spöl River	Low	Low	High	Low	Low	Medium
22	Sandey River	Low	Low	Low	Low	Low	Low

In order to obtain an overview of the evolution of water demand at the Pilot Sites, data on current as well as estimated future water demand (for 2050) were collected for the following sectors: drinking water supply (permanent and tourist population), industrial production, artificial snow production, irrigation, cattle water supply, hydropower generation, and fisheries. Figure 8 illustrates the current and forecasted ranked water uses for the Alp-Water-Scarce Pilot Sites. For improved comparison, the water uses are normalized to the area and expressed in l/s km^2. Due to a lack of data, no future estimation could be made for the following sites: Entella, Scrivia, Karawanke, Spöl, and Sandey. For the Noce site, no future estimations were made because it was impossible to quantify the number of tourists and migration rates for 2050.

**FIGURE 7:
The Alp-Water-Scarce
Pilot Sites.**

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Current high water usages can be observed at some Italian Pilot Sites (e.g., Piave, Entella, and Noce), which is due to high water demand for irrigation purposes. Furthermore, the Lower Gurktal (Austria), a small area delivering drinking water from wells to the capital of Klagenfurt, shows high water usage that will increase until 2050. In any case, for most of the sites no drastic changes (in terms of quantity or sectors) in water usage are expected in the future.

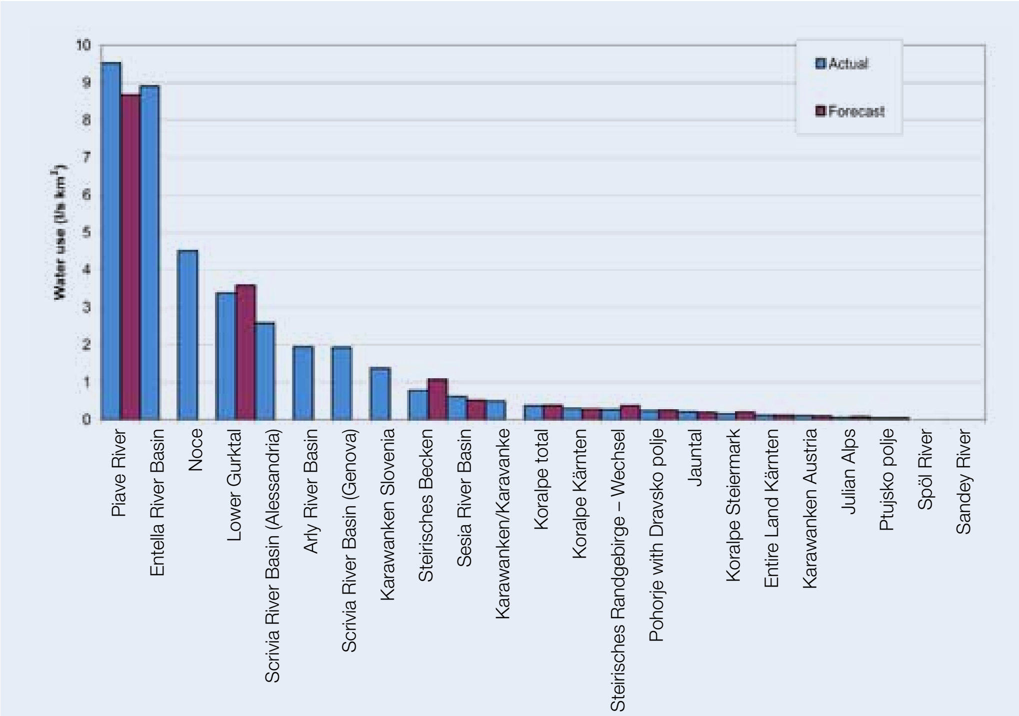


FIGURE 8: Ranked water use at the Pilot Sites in l/s km^2.

3.1 Water Scarcity and Drinking Water Supply

Impacts of climate change on drinking water supply

In all regions across the Alpine Arc, the supply of drinking water for the population remains the highest priority in periods of crisis. Water cuts and the emergency supply of drinking water for residents via trucks (as occurred, e.g., in 2009 in the Entella river basin, Italy) must be avoided for safety and political reasons.

Drinking water can have various sources: groundwater from deep aquifers, springs, or river bank filtrates, or surface water from large rivers, small torrents, natural or artificial lakes, etc. These different sources may be vulnerable to a variety of hazards:

– Deep aquifers may store contaminants that can be accumulated or transported over a long time period before being dissolved or arriving at wells and springs (pesticides, heavy metals, etc.). An increase in temperature and evapotranspiration might increase the vulnerability of these systems due to a decrease in the recharge of the aquifer.
– Large rivers are also a significant source of drinking water supply. This source is vulnerable to water pollution (industrial and agricultural, sewer overflows, etc.). Drought conditions (likely to be more frequent in the future) also increase the risk of water scarcity in terms of quality.
– Small torrents as well as head basin springs are greatly influenced by climate warming, as the precipitation stored as snow and glaciers is significantly diminishing. This drinking water source is thus highly vulnerable to climate warming if rainwater in winter does not recharge the aquifers. Furthermore, it is also expected that the melting of permafrost can increase the release of heavy metals.
– Natural and artificial lakes are vulnerable to agricultural, urban, and industrial pollution that may be stored in lakes. Moreover, the ecology of lakes is complex, and disequilibrium can lead to poor water quality (e.g., eutrophication) that may increase water scarcity.

For the Alp-Water-Scarce Pilot Sites, an overview of the sources of drinking water is given in Table 3.

TABLE 3: Sources of drinking water at the Alp-Water-Scarce Pilot Sites ("++" – very important; "+" important; "-" not important)

*Data from Pilot Sites 15 "Fresina" and 17 "Adige" are missing, since only experiments were performed at these sites. No other data were collected. * For the Pilot Sites Entella and Scrivia River Basin (Genova), no differentiation between "surface water large rivers" and "surface water small torrents" is made.*

ID	Site	Deep aquifers	Springs	Surface water large rivers	Surface water small torrents	Shallow ground-water	Artificial lakes
1	Savoy	+	++	-	-	+	-
2	Arly River Basin	-	++	-	-	+	-
3	Koralpe	-	++	-	-	-	-
4	Karawanken/Karavanke	+	++	-	-	-	-
5	Jauntal	-	-	-	-	++	-
6	Lower Gurktal	-	-	-	-	++	-
7	Steirisches Becken	++	-	-	-	+	-
8	Steirisches Randgebirge – Wechsel	-	++	-	-	-	-
9	Entire Land Kärnten	-	++	-	-	++	-
10	Pohorje with Dravsko polje	++	+	++	+	++	-
11	Ptujsko polje	++	+	++	+	++	-
12	Scrivia River Basin (Alessandria)	+	-	-	++	++	+
13	Julian Alps	-	++	-	-	++	-
14	Piave River	+	++	-	-	-	-
16	Noce	-	++	-	+	-	-
18	Entella River Basin	+	-	*	++	-	-
19	Scrivia River Basin (Genova)	+	-	*	++	-	-
20	Sesia River Basin	+	++	-	+	+	-
21	Spöl River	-	-	++	+	-	-
22	Sandey River	-	-	-	-	-	-

Mechanisms and measures to ensure drinking water supply in periods of water scarcity

It can generally be said that critical situations for drinking water supply occur due to a permanent or temporary reduction of available water resources. The possibilities of how to deal with such water shortages over the short and long term depend on various local factors:

– Is the local water extraction or the inflow from other water suppliers flexible enough to compensate for the elimination of individual extraction areas?
– Do competing water uses exist and will they increase in the future (e.g., irrigation, tourism)?
– How will water demand develop in the future?

Furthermore, reduction of available water resources is coupled with the following parameters:

– A permanent or seasonal decline in groundwater recharge with lower groundwater levels, which reduces the amount of available water resources.
– Spring discharges may decrease with the reduction of available water.
– Groundwater quality may degrade due to declining dilution of contaminated groundwater resources.
– Weather events including heavy rainfall and floods, but also long periods of droughts can cause problems in the operating procedure of water suppliers.
– Increasing water demand during hot and dry periods in combination with decreasing water resources may lead to local water scarcity.
– Competing interests between different users (water supply, agriculture, energy, trade and industry) may occur if the available water resources are low.

In order to mitigate the risk of water scarcity, drinking water suppliers should implement a comprehensive situation analysis that can serve as a basis for appropriate adaptation measures. Such a situation analysis should be accompanied by information, communication, and training activities for water suppliers. When performing such a situation analysis, the following questions must be taken into account:

– What are the parameters – apart from climate change - that affect the supply system?
– What are the system components or processes that are particularly vulnerable to expected impacts?
– Which types of customization options are possible in ongoing operation and management activities?
– How should investments be applied in the future?

A so-called "Water Safety Plan" (not based on a law; efforts were made to include it in the drinking water directive but were unsuccessful; for more information, see WHO http://www.who.int/water_sanitation_health/dwq/WSP/en/index.html; ÖVGW, 2008) would provide a good strategic foundation for management of the drinking water supply for a region that might be affected by water scarcity. It comprises all parameters that concern the drinking water supply system. In addition, the impacts of these parameters are weighted in order to create a catalog of measures to prevent or remedy the effects of water shortage.

In order to identify the impacts of climate change on water resources for drinking water supply systems, ongoing measurements at water dispensers (springs, wells) are necessary. Only long-term records enable the identification of trends and the creation of long-term water resource forecasts. Furthermore, such regional and national long-term measurements are the main basis for the operation of an early warning system to detect water scarcity that provides the operators and suppliers of drinking water with the necessary information to ensure the drinking water supply. In order to activate necessary measures at short notice, appropriate planning and technical procedures must be implemented in advance to adjust the water supply system to climate change. These measures can range from resource protection to the collection, treatment, and distribution of water, to management actions.

3.2 Water Scarcity and Agriculture

General impacts of climate change on agriculture

Agriculture is one of the most climate-sensitive sectors in the economy. It is linked to climate change in three ways: agriculture can cause, solve, or be affected by climate change. Water consumption in agriculture varies greatly, depending on the actual land use type (grassland, arable land, special crops, vineyards, orchards) or type of animal husbandry. Climate change in general will affect the suitability of areas for agricultural use. As a consequence of the many expected regional climate changes – such as higher temperatures, rising evapotranspiration and heat stress, more frequent extreme weather events, varying precipitation and water supply, decreasing duration of snow cover, changing infestation patterns, higher CO2 and O2 concentrations, and increasing UV radiation – agriculture will need to adapt to minimize risks to production. The expected changes in the climate will influence vegetation periods as well as the quantity and quality of crops, and will additionally have indirect consequences for harvesting conditions, for availability of water and nutrients, and for the transport, storage, and processing of products. Climate change will directly influence livestock husbandry by impacting animal health, growth, and reproduction, and also indirectly by affecting the productivity of pastures and forage crops. Agriculture is additionally connected to up- and downstream industries; as a result, the manifold interdependencies between different economic sectors should be taken into account when measuring the overall effects of climate change. Apart from the direct effects of climate change on agriculture, the new climate and weather conditions will also have consequences for natural hazards, tourism patterns, and regional development, all of which may have an additional impact on agriculture, particularly in view of regional economies.

Development of regional indicators for describing water scarcity risks in agriculture
To meet the goals of Alp-Water-Scarce, a system of the most relevant agricultural indicators was developed, including plant cultivation, livestock husbandry, and soil and climate conditions (Figure 9):

- Water consumption for plant cultivation: Proportions of specific cultivated plants on agricultural land weighted according to the crop coefficient (which includes evapotranspiration)
- Water consumption for livestock husbandry: Proportions of specific livestock units weighted according to specific water demand
- Irrigation: Proportion of irrigated areas on agricultural land
- Soil: Proportion of soils weighted according to the capacity of available water in the soil
- Climate: Regional and monthly aridity (in relation to temperature and precipitation)

The estimate of future regional climate conditions is based on climate indicators that have been assessed in the RECLIP model (http://foresight.ait.ac.at/SE/projects/reclip/) for 2050. Future plant cultivation and livestock indicators are based on common agricultural scenarios derived from the literature and expert discussions and opinions.

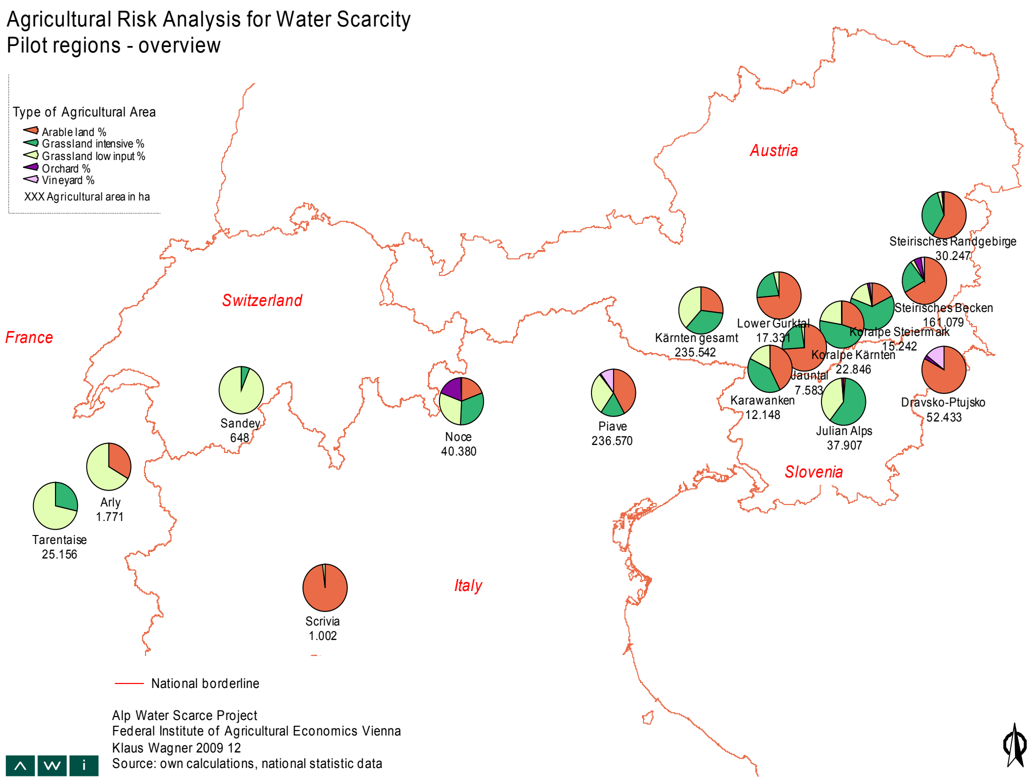
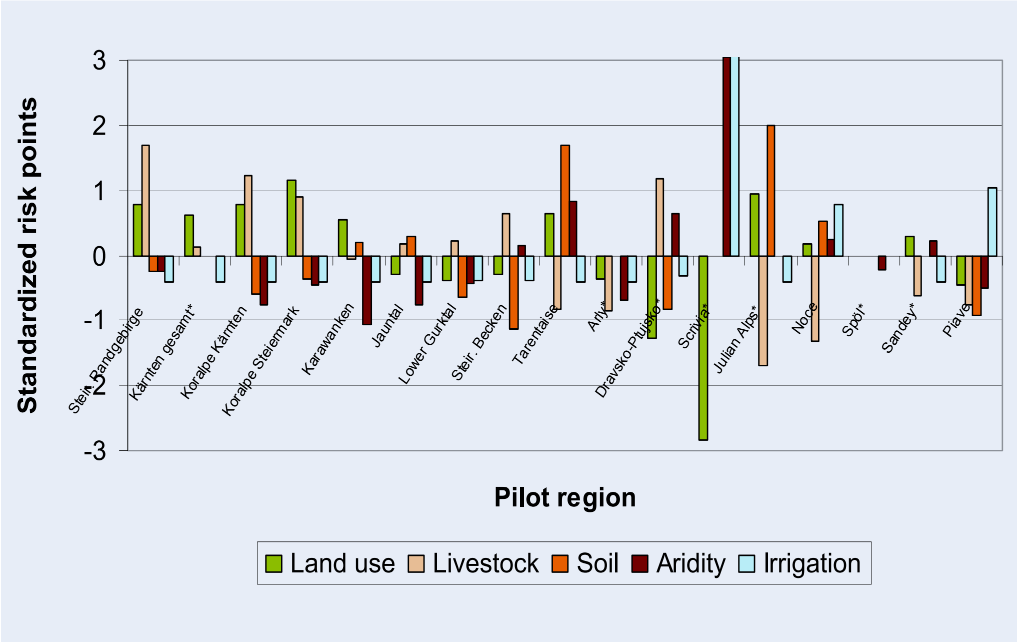


FIGURE 9:
Current agricultural land use for those Pilot Sites with available data.

The developed indicator set has been analysed for selected Alp-Water-Scarce Pilot Sites to illustrate a broad range of present and future water-scarcity risk patterns for agriculture. The present situation shows a relatively higher risk of water scarcity due to land use and livestock in the eastern regions of Austria and Slovenia; for example, in the Steirisches Randgebirge, Koralpe, and Dravsko-Ptujsko. The western and southern regions of France, Slovenia, and Italy (e.g., Tarentaise, Scrivia (Alessandria), Noce, and the Julian Alps) are characterised by relatively poorer soil and climate indicators. The Italian regions in particular currently rely to a great extent on irrigation (Figure 10).

To summarise the rough assessment of future regional climate situations and future scenarios for agriculture, it was possible to determine which regions would be either more or less affected by future water scarcity in comparison to their current situation. In Tarentaise, a slight increase in aridity will be accompanied by a higher risk classification for land use. In Noce, a considerable increase in aridity could be coupled with a higher risk classification for agricultural land use. For the Scrivia river basin (Alessandria), the land use risk classification will drop slightly, but aridity will increase greatly and the amount of irrigation, which is already very high, will increase accordingly. The Slovenian region Dravsko-Ptujsko will suffer from higher aridity accompanied by a higher risk classification for agricultural land use. This could be a problem for the production of silage and grain maize, especially since periods of water scarcity occur mostly during the time when plants are most sensitive to their effects. As a result, substitute cultures that are adaptable to the changing water supply will need to be found, including crops that can replace essential cattle feed, since cattle breeding is very important to that region. The Austrian regions, too, will face higher aridity, but the risk classification of agricultural land use in most Austrian regions will not increase.

FIGURE 10:
Standardised risk classification for selected Alp-Water-Scarce Pilot Sites, current situation.
***Data incomplete.**



3.3 Water Scarcity and Hydropower Generation

General overview of hydropower generation and climate change

Hydropower production is very sensitive to climate change and water scarcity (Iimi 2007). Especially in mountainous areas like the Alps, the hydrological regime strongly depends on water accumulation in the form of snow and ice and the corresponding melting process. Present climate change, in particular changes in temperature, affect the hydrological regime and create substantial problems in the management of water for hydropower production (Zierl & Bugmann 2005; Schaefli et al. 2007). However, despite the importance of hydropower production and its potential sensitivity to climate change, in particular in the Alps, relatively few studies have addressed this issue and predictions at the regional Alpine scale are very limited (Schaefli et al. 2007).

The impacts of water scarcity on hydropower generation: case studies

In Switzerland, hydropower accounts for almost 56% of domestic electricity production. At present there are 556 hydropower plants in Switzerland, each with an engine performance of at least 300 kilowatts. Each plant produces on average ca. 35830 gigawatt hours (GWh) per annum, 47% of which is produced by run-of-river power plants, 49% by storage power plants, and approximately 4% by pumped storage power plants. Two-thirds of the hydroelectricity is generated in the mountain cantons of Uri, Grisons, Ticino, and Valais, although Aargau and Bern also generate significant quantities. Roughly 11% of Switzerland's hydropower generation comes from facilities situated on bodies of water along the country's borders. The hydropower market is worth around 2 billion Swiss francs (basis = delivery from power plant at 5 cents per kilowatt hour), and is therefore an important segment of Switzerland's energy industry. In the future, the federal government would like to promote the use of hydropower to a greater extent through a variety of measures. In order to exploit this realizable potential, existing power plants are to be renovated and expanded in compliance with the relevant ecological requirements. The instruments to be used here include cost-covering remuneration for feed-in to the electricity grid for hydropower plants with a capacity of up to 10 megawatts, as well as measures aimed at promoting hydropower included in the "Renewable Energy" action plan (Swiss Federal Office of Energy 2011). In terms of quantity, the goal is to increase the mean estimated production level by at least 2000 GWh in comparison to the level recorded in 2000 by renovating existing hydropower plants and constructing new ones (Swiss Federal Office of Energy 2011).

In Italy in the period 2002-2009, the average annual production of hydroelectric power was 45700 GWh (86% by run-of-river and storage power plants and 14% by pumped storage water plants). The mean contribution of hydropower to the total production was about 15% and the contribution to renewable production was 85% (Authority for Electricity and Gas 2011). A certain amount of hydropower production is produced in the Alpine area, for example, in the catchment of the Piave River in the Southern Alps. The installed power is about 850 MW and the annual production is 3000 GWh, which is 1% of the total national production and 7% of the renewable production of Italy. In the past two years in the Piave catchment, at least 20 projects of mini hydropower installations have been realized, with a total power of 8 MW and a yearly production of 50 MWh. This increase in the number of small hydroelectric power plants was encouraged by the European directive 2001/77/EC (EC 2001). Despite the importance of hydropower as an energy source, relatively little is known about the impact of future climate change and water scarcity on hydropower production.

In 2007, the study "Hydropower production under a changing climate" was initiated by Swisselectric and the Swiss Federal Office of Energy in collaboration with Swiss universities (Hänggi & Plattner 2009). The project has published the results of a pre-study to evaluate the state-of-the-art regarding hydropower production and climate change as a basis for targeting future goals. From this study, it can be assumed that in the short term, hydropower plants located in glacial catchments will compensate for decreasing precipitation in dry years by increases in glacial melt. For example, in the summer of 2003, energy production by hydropower was only 0.8 % below the average of the previous 10 years, even though the yearly average of precipitation was as much as 30% lower compared to the average. However, long-term hydropower production is predicted to stagnate or even decrease because of decreasing precipitation, glacier retreat, and increasing evapotranspiration. For Switzerland, it is estimated that there will be a 7% reduction in the production of hydropower electricity in the year 2050 due to increasing temperatures and drought effects (OcCC 2007). If drought is temporarily limited, power stations with reservoirs should be less affected than river power plants.

For Italy, the trend in temperature also shows some periods with a very fast increase; in the last 20 years in particular, temperatures are well above the long-term average. At the HISTALP station at Belluno, for example, the temperature increase is variable over the year, but is much more notable in winter and spring, and the month with the greatest increase is May (+2.2 °C). The annual amount of precipitation shows no clear trend, although the regime of precipitation appears to have changed, with less rain in winter and early spring (from December to March) and a slight increase in the other months. The main effects of climate change on hydroelectric production will be caused by differences in water availability during the year (i.e., seasonal variability). In the Italian Alps, many dams were built at the tongues of glaciers to store the large amount of water released during the summer for the purpose of using this water in winter for hydroelectric power production. In the Piave catchment, the loss in volume of the Marmolada Glacier will significantly affect the inflow to Fedaia Lake. This lake is filled in late spring and summer, and the water is then used for hydroelectric power production in autumn and winter. Increases in temperature and shrinkage of the glacier will cause a decrease in water in the summer; i.e., the lake will be filled during spring with water from snow melt but will lack the additional contribution of melt water from the glacier in the summer. For Alpine glaciers, especially in inner dry zones, the annual balance is mainly linked to summer temperatures and reflection (related to summer snowfall) rather than to winter accumulation (Schöner 2009). An example of this trend can be seen in data from the hydrological year 2008-2009: even though the winter produced the most snow since 1951, the annual balance for glaciers was negative.

In addition to direct climate impacts on water availability, climate change can also trigger changes in the catchment where hydropower is generated, e.g., through higher frequency of severe precipitation events leading to higher sediment loads that subsequently increase the maintenance requirements for plant facilities such as reservoirs. From a risk management perspective, increasing severity of precipitation events and the thawing of permafrost can lead to landslides, affecting reservoirs and downstream areas.

In general, the future contribution of hydropower in relation to other sustainable energy sources under conditions of climate change is unclear. Furthermore, there is an urgent need to clarify how water will be optimally distributed during periods of long-term low flows or droughts in terms of resource conflicts between industry, drinking water supply, hydropower production, agriculture, ecology, etc.

3.4 Water Scarcity and Tourism

General impacts of climate change on tourism

Tourism is one of the principal factors of economic development in mountain territories. In a prospective approach, it is thus important to analyse the potential effects of climate change on this sector.

From the perspective of water management, two main impacts of climate change on mountain tourism can be identified: 1) climate change directly impacts the water resources mobilized for the development of tourist activities (drinking water, snow cover, water landscape); 2) climate change might influence customer behaviour and, consequently, the tourism industry and related water needs.

1. **Climate change and water resources mobilized for tourist activities**

   The precise quantification of the impact of climate change on water resources is a challenging task. Nevertheless, the following evidence is already clear: a reduction in the duration and quality of snow cover is increasing the vulnerability of winter ski resorts to the deficit of snow (Abegg 2007; OECD 2007; Steiger 2008).

   This consequence, which is to a large extent a socio-economic problem (loss of ski activity in the territories involved) also has an impact on the water sector. In fact, artificial snow is already being produced to mitigate the effects of the lack of sufficient snow. On average, in France, 23% of the area of ski slopes is equipped with artificial snowmaking facilities, compared to 70% in Italy, 59% in Austria, and 33% in Switzerland. In France, more than 5000 hectares are supplied with artificial snowmaking facilities. Each hectare so equipped requires about 3500m3 of water per winter (Paccard 2010, Figure 11).

   If the quantity of water used for artificial snowmaking is not significant at the regional scale and in relative value, the impact can be important at the local scale, i.e., on small rivers in the upper basins (Reiter 2008). Thus, the development of artificial snowmaking, whenever it is justified, must necessarily take environmental impacts into account (e.g., water quality and quantity).

FIGURE 11:
Artificial reservoir for snowmaking at the "Valloire" ski resort (France).

A reduction in precipitation and an increase in evapotranspiration has a quantitative impact on the availability of water resources, e.g., on the drinking water supply of mountain municipalities with tourist resorts.
This is the case for several springs in Savoie, France. For example, at the "Les Frasses" spring in the commune of "Macôt-la-Plagne" (Figure 12) one of the communes of the "La Plagne" winter ski resort, the rainfall deficit during 2009 led to record low discharge levels compared to those observed over the 10 previous years during the same seasons (Conseil Général de la Savoie 2010).
Of course, this particular case cannot be extended to all the springs in Savoie, which are not in the same situation. Moreover, it is difficult to directly and causally link the reduction in precipitation over these 10 years in Savoie to the consequences of climate change. Nevertheless, the managers of the water networks must anticipate such situations to avoid any risk of water scarcity (i.e., by common management of water resources and by inter-connecting networks).

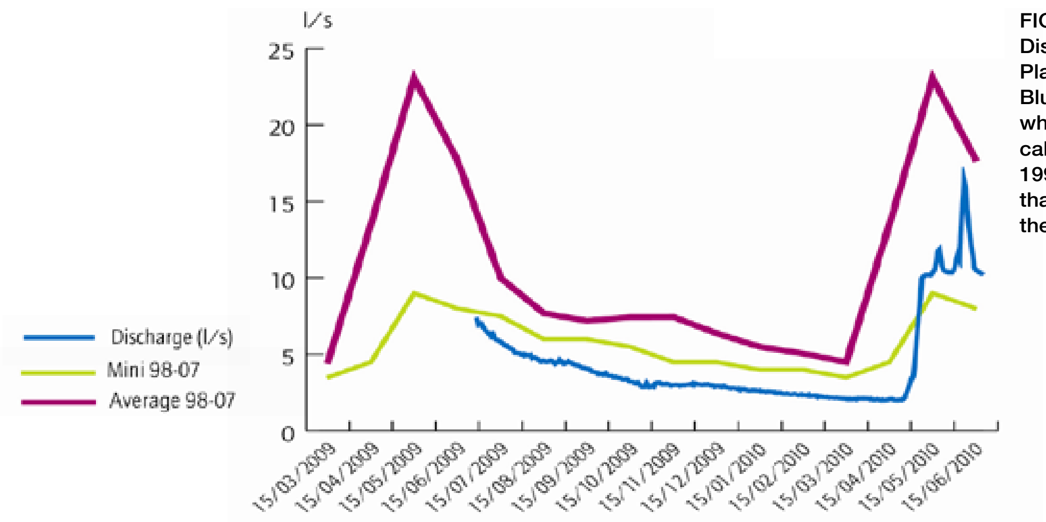


FIGURE 12:
Discharge of the "Macôt-la-Plagne" spring (2009-2010). Blue: discharge 2009-2010, which was lower than the calculated average in the period 1998-2007 (purple line) and lower than the measured minima over the same period (green line).

To a lesser extent, two other consequences for water resources are possible:

- A modification of the hydrological regime (low water levels in summer, even dry rivers, and more markedly extreme pluviometric events) that might affect tourist activities on rivers and certain lakes (water sports, hiking, and camping) (Elssasser & Bürki 2005), and
- A deterioration of the glacial landscapes "considered as typical", which might lead to a loss in touristic attractiveness for certain mountain territories (Abegg 2008; GT "Savoie 2020" 2010).

2. **Climate change and customer behaviour, touristic offerings, and induced water needs**
   Climate change might affect the behaviour of tourists by prompting changes in choice of destinations and consumption patterns, among other issues. As a result, the offer of tourism services will adapt, indirectly affecting water resources. The following are possible predictions for mountainous areas:
   - Tourists from lower and medium altitudes might move up to the ski resorts at higher altitudes, increasing the demand for drinking water at these resorts. Furthermore, artificial snowmaking must be considered also at higher elevations (EEA 2009; OECD 2007).
   - An increase in summer heat waves in valleys and plains could benefit mountain tourism, where the temperature effects are more nuanced (Müller & Weber 2008), leading to an increase in drinking water demand at higher elevations.

4 Overview of the European and National Legal Frameworks

4.1 European Legal and Technical Framework

Consideration of mitigation and adaptation measures related to water scarcity at the Alpine level necessarily means taking into account European and national legal frameworks for water management. The following chapters provide an overview of the legislative measures and directives in force at the European level as well as on a national level for the following Alpine countries: Austria, France, Italy, Slovenia, and Switzerland (for details, please see the Annex).

The Water Framework Directive

The Water Framework Directive (WFD), adopted by the European Parliament in October 2000 (WFD 2000), is the main European directive concerning water management. One of its stated objectives is that the European water bodies should achieve so-called "good ecological status" by 2015. Although the WFD deals primarily with aspects of water quality, issues of quantity cannot be neglected since the two aspects are closely linked. Some articles of the WFD make reference to the issues of water quantity and mitigation of drought (WFD, Preamble (19), (32); article 1 paragraph; article 4 paragraph 6; article 11 paragraph 5); however, the issue of "water scarcity" is not explicitly addressed. Furthermore, "the measures which directly relate to drought mitigation are left as optional supplementary measures" (EurAqua 2004). Nevertheless, the WFD allows Member States a certain flexibility when implementing the Directive in the case of drought periods: "There may be grounds for exemptions from the requirement to prevent further deterioration or to achieve good status under specific conditions if the failure is the result of unforeseen or exceptional circumstances, in particular floods and droughts" (WFD, Preamble (32)).

Member State Perspective

The Member States of the European Union have had the opportunity to express their opinions on the extent to which the WFD allows them to address water scarcity and droughts. Article 11 (Programme of measures), which allows consideration of issues of quantity of water resources in developing programmes of measures, is of particular importance. Furthermore, some Member States stress the fact that the implementation of the WFD is an opportunity to make demand-side measures a priority. Other Member States also point out the importance of article 9 and annex III (principle of recovery of costs for water services, in accordance in particular with the polluter-pays principle) in solving water stress issues. With regard to droughts, Member States recognize the usefulness of article 13.5 of the WFD, which allows the addition of supplementary provisions to River Basin Management Plans to deal with this phenomenon. Within Alp-Water-Scarce, certain Pilot Sites (e.g., Noce and Scrivia River Basin) are implementing programmes and management plans to adapt water management to drought issues in their areas.

EU objectives and policies regarding water scarcity and droughts

After the drought of 2003 and its widespread impact on European countries, the discussion of how to deal with water scarcity and drought gained momentum in the European Union. The creation of the European Drought Centre in 2005 (http://www.geo.uio.no/edc/) can be seen as one of the results. In addition, in 2007 the Commission issued a communication to the European Parliament and the European Council concerning this problem (EC 2007). The Environmental Council supported the Commission's 2007 Communication, inviting the Commission to review and further develop a water scarcity and drought policy by 2012. Updates on the implementation of the recommendations proposed in the 2007 communication are issued every year by the Member States. Moreover, in 2008 the DG Environment published a report on drought management plans in the EU (DG Environment 2008).

1. **Communication of 2007**

   In its Communication of 2007 (EC 2007), the European Commission lists the challenges to be addressed regarding water scarcity and drought as follows:
   - To fully implement the WFD
   - To develop effective water pricing policies (especially the user-pays principle)
   - To encourage sustainable land use planning
   - To make water-saving and water efficiency measures a priority in Europe
   - To further integrate water-related concerns into water-related sectoral policies (in order to move towards a water-saving culture)
   - To develop research on these topics to make available high-quality knowledge and information.

   The measures emphasised by the European Commission are all focused on confronting the issue before a drought crisis occurs. They involve long-term measures to achieve the sustainable management of water resources with regard to its quantity. Furthermore, the measures are aimed at lowering the pressures on water resources, for example, by implementing a sustainable land use planning policy and consequently controlling new tourism-related infrastructure development to be consistent with the availability of water. By developing water-saving measures and implementing water-pricing policies, the Commission seeks to encourage Member States to improve water demand management. In the 2007 Communication, there is little mention of after-crisis measures or supply-orientated measures.

2. **Report of 2011, objectives for 2012, and current developments**

   In 2011, the "Third Follow up Report to the Communication on water scarcity and droughts in the European Union COM (2007) 414 final" (EC 2011) was published as a continuation of the first and the second reports from 2008 (EC 2008) and 2009 (EC 2010).

This report is based upon responses from 21 countries to the Commission's annual questionnaire. From the Alpine Space countries, France reported that "they faced droughts or rainfall levels lower than the long-term average" and "experienced local limited water scarcity occurrences". Consequenty, mitigation actions were developed and restrictions were applied in order to restrict water use in France. Austria and Switzerland reported that they did not experience any drought or water scarcity situations.

By the end of 2012, the Commission intends to implement a "Blueprint" to "…safeguard Europe's waters…" (EC 2011) that will:

- "look back and assess the implementation and achievements of policies and measures in place to ensure the protection and availability of EU water resources, while identifying gaps and shortcomings".
- "look forward at the evolving vulnerability of the water environment to identify measures and tools that will be needed in several EU policy areas in order to ensure a sustainable use of water in the EU in the long term".

Furthermore, the Blueprint will synthesise policy recommendations and will be accompanied by a number of new initiatives, including measures of a legislative nature if appropriate.

For the water scarcity and drought policy review, the Commission has identified the following principal building blocks:

Improving water efficiency

- Water efficiency of buildings
- Reduction of leakages in distribution systems (Austria, France, and Italy report that activities have taken place regarding this item)
- Water efficiency in agriculture
- Halting desertification

Better planning

In the countries that partcipated in the Alp-Water-Scarce project, the following measures were taken: activities regarding the reduction of water consumption (Austria, France, and Italy); adaptation to climate change (Austria and Switzerland); and integration of water scarctiy and drought actions into River Basin Management Plans (Italy).

Furthermore, the following actions are scheduled to take place:

- Implementation of the River Basin Management Plans
- Further development of the observatory and an early warning system for droughts
- Data collection and establishment of a comprehensive indicator framework

3. Drought and Water Scarcity Management Plan

In 2008, the European Commission published a technical report (DG Environment 2008) on drought management. The idea of this "Drought Management Plan" was to develop risk management-based approaches. In light of the drought periods experienced across Europe in recent years, it was considered necessary to move from crisis management planning to long-term planning.

One recommendation to achieve this objective is that river basin authorities should establish an indicator system to identify and predict possible impacts of droughts and draw up associated measures to be applied in their catchments. The set of indicators can be divided into two main types: indicators to evaluate the preparation for an event and those that characterize the event itself when it happens. The Member States are able to select the indicators they need.

According to the European Commission, a "Drought Management Plan" should consist of three basic elements that must be established at the river basin level through a transparent process involving public participation:

a) A drought early warning system
b) Drought indicators correlated to thresholds for the different stages of drought as it intensifies and recedes
c) Measures to achieve specific objectives in each drought phase

In its report, the European Commission lists some indicators that could facilitate the prediction and management of droughts:

- stored surface reservoir volumes
- water levels of aquifers
- soil moisture content
- river flows
- reservoir outflows
- effective precipitation (in representative control points)
- snow reserves (for areas where it is significant)
- indicators from quality and environmental networks

The establishment and validation of thresholds can be achieved by using historical drought data to check the accuracy of indicators and by comparing simulation models of river basins with indicator values.

Classifying the indicators and defining appropriate thresholds should allow the river basin authorities to set up early warning systems to confront water scarcity and define a classification according to the severity of the drought. According to the status defined, special measures should be implemented:

- Normal status: long-term measures and hydrological planning.
- Pre-alert status: preventing the deterioration of water bodies while ensuring the activation of specific drought management measures and continuing to meet water demand.
- Alert status: preventing the deterioration of water bodies and saving water. Demand restrictions should be implemented.
- Emergency or extreme status: water resources are insufficient to meet water needs. Measures must be taken to satisfy water demand and to reduce the impact on aquatic ecosystems.

"Drought Management Plans" should be based on an integrated approach that also takes into account how the available water should be allocated among different users during drought events.

4. The European Commission White Paper

A European Commission White Paper (COM 2009) was issued in April 2009 with the objective to define a regulatory framework to reduce the vulnerability of the European territory to climate change. Parts of the report are related to water management in a changing climate; actions regarding water scarcity and droughts are proposed, including:

- The promotion of strategies to increase the resilience of health, property, and the productive functions of land to climate change, inter alia by improving the management of water resources and ecosystems;
- The development of guidelines and a set of tools (guidance and exchange of best practices) by the end of 2009 to ensure that the River Basin Management Plans are climate-proof;
- An assessment of additional measures to enhance water efficiency in agriculture, households, and buildings (especially to address water scarcity);
- An exploration of the potential for policies and measures to improve the ecosystem storage capacity (to increase drought resilience and reduce flood risks) for water bodies in Europe.

5. Agricultural policy measures with impact on water consumption

The present Common Agricultural Policy (CAP) provides a basic level of income security to farmers, as well as a framework for sustainable management of the natural environment in which agricultural activity takes place. The shift from production-linked support to decoupled aid enables farmers to respond flexibly to external requirements, market signals, and developments resulting from climate change. Cross-compliance links the full receipt of CAP payments – including some rural development payments – to the respective EU legislation on the environment; on public, animal, and plant health (including animal welfare); and on maintenance of the agricultural and environmental

condition of farmed land. Requirements governing the maintenance of permanent pastures, as well as those governing specific soil practices to avoid erosion and retain organic matter, contribute both to the sustainable use of resources and to adaptation. The Farm Advisory System ensures the availability to farmers of advice oriented towards the basic environmental requirements. Facilitating farmers' access to risk-management tools, such as insurance schemes or mutual funds, also helps them to cope with the economic consequences of greater fluctuations in crop yields, animal diseases, and weather events. In the CAP Health Check, Member States have been given the option of using part of their national financial envelopes for risk-management tools within CAP support. This represents a further step in the direction of sustainable agriculture with a specific emphasis on climate change mitigation and adaptation, water, and biodiversity protection, for which additional rural development funding has been approved (COM 2009).
With rural development policy increasing in importance in the CAP, the Member States are now offered a range of measures that provide targeted support for activities that also contribute to adaptation to climate change. The rural development framework can make a vital contribution to adaptation, as farm-level, local, and regional adaptation requires a policy environment that strengthens the conditions for adaptive action. Under the competitiveness axis, support for farm modernisation and the restoration of agricultural production potential can sustain adaptation to climatic change. For example, preventive mechanisms that combat the adverse effects of climate-related extreme events (e.g., the construction of hail nets) and the adaptation of buildings (e.g., for housing livestock) can be supported. Improved measures and the development of infrastructure offer possibilities for addressing water management issues, thus complementing modernisation measures that provide support for water-saving investments and more efficient irrigation equipment. Support for diversifying crop patterns, structures, agricultural activities, and for diversification into non-agricultural activities is available under axes 2 and 3. This helps make production systems more resilient to both economic and climatic factors, as diversification is a key factor for the stability of agricultural income. In the environmental and land management axis, agro-environmental schemes targeted at better management of soil, water, and landscape play an important role. Investing in human capital is an EU priority for rural development, and will also be a key factor with a view to coping with climate risks. All Member States devote support to training, information, and knowledge diffusion oriented towards improvement of farm management, methods for harvesting and livestock production, and environmental land management. Support can also be provided for establishment of farm management and advisory services as well as for their use by farmers. Rural development furthermore plays a role in the conservation and sustainable use of genetic resources. This contributes to the maintenance of a broad genetic resource base, which in turn can facilitate the selection of genetic material resistant to changing diseases and pests, as well as the development of varieties that are more tolerant to heat and water stress.

The implementation of EU CAP measures varies among the countries with Alp-Water-Scarce Pilot Sites (Table 4): some (France, Italy) maintain a focus on the first pillar (market interventions, coupled subsidies and direct payments for agriculture), others (Austria, Slovenia) on the second pillar (rural development). Concerning water consumption in agriculture, analyses show that there is no focus on agricultural measures that give direct incentives to higher water consumption, but there are a number of measures that are at least indifferent in their effect (on water consumption). Especially in France and Austria, measures with indifferent effect comprise between 2/3 and 3/4 of all subsidies; in contrast, in Italy and Slovenia the share of measures having an indifferent effect and those with a positive effect are more balanced.

TABLE 4: Implementation of Common Agricultural Policy measures (and comparable measures in Switzerland) with potential effects on water consumption in countries with Alp-Water-Scarce Pilot Sites.

Measure category	Type of effect related to water scarcity	AT	FR	IT	SI	CH
Decoupled direct payments	Indirect, positive	X	X	X	X	X
Coupled direct payments	Direct, positive	X	X	X	X	X
Market regulation measures	Direct / indirect, positive / indifferent / negative	X	X	X	X	X
Rural development – Competitiveness	Direct, positive	X	-	X	X	X
Rural development – Environment and countryside	Direct / indirect positive / indifferent	X	X	X	X	X
Rural development – Quality of life and diversification	Indirect, indifferent	X	-	X	-	X
Leader	Indirect / indifferent	X	X	X	X	-

Sources: A: Federal Ministry of Agriculture, Forestry, Environment and Water Management data pool, 2010; F, I, SI: European Union Directorate-General for Agriculture and Rural Development, 2010, information from Pilot Site project partners; CH Federal Office for Agriculture, 2010.

4.2 Water Governance in Austria, France, Italy, Slovenia, and Switzerland

In the annex, a detailed description of water governance related to water scarcity and drought is provided for Austria, France, Italy, Slovenia, and Switzerland. Due to the complexity of the topic, a summary of the most important aspects is provided in Table 5.

TABLE 5: Overview of water management aspects regarding water scarcity and drought for Austria, France, Italy, Slovenia, and Switzerland.

	Austria	France
Ownership / public	Listed in Annex A of the *Wasserrechtsgesetz* (Water Act).	Registered as part of the fluvial public estate *(Domaine Public Fluvial).*
Ownership / private	Groundwater, springs, water in wells and ponds, etc., on certain private land belongs to the landowner.	Water bodies not registered as state-owned (e.g., smaller water bodies) belong to the riverside residents. Each riverside resident owns the riverbed up to its centre within the boundaries of the property.
Competences / national	Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management (e.g., technical coordination of the activities of the water management authorities in the provinces).	Ministry of Ecology, Sustainable Development, Transportation, and Housing.
Competences / NUTS2	The head of the province is the planning authority for water management issues (e.g., monitoring, data collection, aggregation of water management questions).	State agencies manage water; the agency generally involved is the DREAL (Regional Agency of Environment, Spatial Planning and Housing).
Competences / NUTS3	When not otherwise stated, the administration of a district is the responsible water management authority at the first level of jurisdiction.	A state representative coordinates water policy at this level (e.g., organizing a consultation before publishing local decrees to limit water usages in case of drought).
Competences / LAU	(not relevant for the project)	The mayor (in municipalities) or the president (in districts) is responsible for drinking water supply, drinking water quality, waste water treatment, risk management, and emergency plans.
Legislation on drought and water scarcity	In the *Wasserrechtsgesetz*, water scarcity is not explicitly mentioned.	The Law on Water and Aquatic Environments also deals with the "conservation of water resources and aquatic environments" and "quantitative management", including issues of water quantity and adaptation to climate change.
Who decides in cases of crises	1. Water providers must undertake all necessary measures to maintain the water supply, e.g., proscriptions against washing cars, watering gardens, filling swimming pools, etc. 2.Public Authorities: Head of district (NUTS3): responsible for catastrophes (e.g., flooding; water scarcity is not directly related to catastrophes); decides upon measures concerning agricultural irrigation up to proscriptions against irrigation. Head of province (NUTS2): interferes directly via water management planning in cases of water scarcity; organizes sub-regional actions (e.g., construction of transmission pipelines).	NUTS3: the *Préfet du Département* decides upon necessary actions at the departmental scale by effecting an *Arrêté sécheresse.* LAU: the mayor can also take decisions to limit water usage at the municipal level by passing an *Arrêté municipal.*

Italy	Slovenia	Switzerland
Since 1994, with the approval of the law n.36, 1994 ***(Legge Galli)***, all water belongs to the Water State Property ***(demanio idrico).*** This law has been repealed, but has been replaced by the d.lgs. n. 152/2006 (esp. art. 144 on public water); for the autonomous provinces, water is provincial property; for all other regions, water is regional property; for the use of public water a concession must be obtained.	All water bodies belong to the state; water consent for public or personal water supply can be obtained; for commercial use, concessions must be obtained and concession fees paid to the government.	Surface water and lakes (Swiss Civil Code art 664, al. 2 CC); important aquifers and springs that recharge bigger surface waters (Art. 704 al. 3CC); the cantons decide what is public (important) or private (unimportant).
None	None	Surface water (precipitation, sewage, drainage; art. 689 and 690 CC). All other springs and groundwater resources (art. 704 al. 1 CC).
The state is responsible for the River Basin Plans, which are binding and must be enforced by all administration and private bodies. The territorial and regional plans and programs must be adapted to the rules of these plans.	Ministry of the Environment and Spatial Planning; the water director is linked to this Ministry, which is responsible for legal and general questions.	The Federal Authority supervises the enforcement of the Federal Law on the Protection of Waters and the implementation of regulations; The Federal Council regulates the co-ordination a) of the water protection measures of cantonal authorities; b) between federal agencies; c) between federal agencies and cantonal authorities
Italian regions must issue a water protection plan, which consists of a plan on the status of water bodies and the quantitative and qualitative management of water. Furthermore, the regions must participate in the permanent institutional Conference of the River Basin Authorities and consequently in the elaboration of River Basin Plans; they must implement the activities prescribed in River Basin Plans.	None	The cantons enforce the regulations of the laws (Law on the Protection of Waters and the Water Protection Ordinance).
None	None	None
Local communities take part in the implementation of water management plans under the framework stated by each region or autonomous province, in compliance with the general rules of competences of local institutions. Consequently, the competences of local communities are defined by national and regional rules and can vary from one NUTS 2 entity to another.	None	The cantons may delegate several tasks of the application of regulations of the law to the community level.
Quality and quantity monitoring of surface and groundwater is carried out by the regions and autonomous provinces, in accordance with European and national rules (e.g., d.lgs. n. 152/2006) and in compliance with the national regulatory enactments on standardization of data. The monitoring of water quantity and usage rules might differ from one region to another.	The "Protection against Natural and Other Disasters Act" mentions, e.g., natural disasters such as earthquakes, floods, landslides, and avalanches, and drought. No exact definitions of the different natural disasters are given. Article 41 requires the preparation of a national program for protection against natural and other disasters. This program is prepared by the Ministry of Defence. The national program also requires the preparation of a “National Plan for the Implementation of the National Program for the Protection against Natural and other Disasters”. The main part of the drought strategy is related to an interministerial working group.	Regulations related to this topic are found in the Water Protection Ordinance "Water withdrawals from watercourses" (Art. 33) and in the Water Protection Law "Conservation of groundwater resources" (Article 43).
For drinking water supply: 1. Less serious episodes (isolated episodes of water scarcity): for autonomous provinces, decisions are made at the municipal level (mayor’s orders); in other parts of Italy, control is given to the Authority of Ambit ***(Autorità d’Ambito)*** within the Territorial Optimal Ambit. 2. Very serious episodes (concomitance of water scarcity and pollution or natural calamity): for autonomous provinces, controlled by the Department for Civil Protection of the Province (e.g., tanks with drinking water supply, temporary connections to alternative sources of water supply); other parts of Italy, controlled by the River Basin Authority.	National: Ministry of Planning and Environment; Ministry of Defence; Ministry of Agriculture, Forestry and Food. Governmental agencies: Defence and Civil Protection Agency; Statistical Office; Agency for the Environment. No operational actions related to drought have yet been performed by the Ministry of Planning and Environment. Since (agricultural) drought in Slovenia is understood as a natural disaster, the Defence and Civil Protection Agency under the auspices of the Ministry of Defence is responsible for the mitigation of natural disasters.	NUT2

Alp-Water-Scarce

4.3 Conclusion

Although a European framework for the management of water scarcity and drought is already in existence or in development, the characteristics of mountainous areas in general and the Alps in particular require special attention due to the following characteristics:

- In valleys, low-flow periods generally occur during the summer (high temperatures and evapotranspiration and an increased amount of water used for human activities; EEA 2009).
- In areas at high altitudes, low-flow periods occur during the winter (less river runoff, water storage in ice and snow).

This spatio-temporal difference regarding the availability of water and the close interconnection and thus resource dependence between mountain areas and their forelands require consideration both in the European and in national legal contexts.

Regarding the national legislation of the five countries that participated in the Alp-Water-Scarce project, legislation specifically dedicated to drought and water scarcity exists only to a limited extent. Possible underlying reasons for this include:

- Current national legislation provides sufficient tools to address water shortages,
- Drought and water scarcity are only a local problem that does not need further attention, and thus future events can be dealt with by applying short-term measures, or
- The problem of water scarcity and drought is so complex that to date no real tools have been or could have been implemented.

Although it seems that the overarching issue is a mixture of all the above-mentioned points, the problems that arise as a result of climate change require adaptation of national legislation to provide efficient tools to address periods of water shortage.

It thus seems important to specifically define the terms “drought” and “water scarcity” in national legislation. Such a definition should be consistent across different sectors (e.g., in Slovenia, the term “drought” only refers to agricultural drought).

Furthermore, the establishment of national drought and water scarcity policies should take into account that already existing tools are sufficient to handle episodic and short-term shortages but would possibly not be adequate to address the consequences of climate change in the long-term. Where not already existing, a clear priority structure for water usage as well as a reconsideration of the current decision-making structure seems necessary.

5 Case Study-Based Recommendations for Water Managers and Policy Makers

The work carried out in the course of the Alp-Water-Scarce project has resulted in a series of recommendations based on case studies performed at the different Pilot Sites. These recommendations and considerations make no complain to be complete but try to contribute to a sustainable water management to mitigate and to tackle water scarcity.
Viviroli et al. (2010) conclude that there is a driving need to promote research and the exchange of knowledge among practitioners. These recommendations have therefore been developed in collaboration with water management experts from across the Alps in a trans-disciplinary and participatory approach.

5.1 Short-Term Measures

5.1.1 Early Warnings of Water Scarcity

Relevance and Case Studies
The establishment of early warning systems to guard against water scarcity or drought has been recommended in several EU regulations and directives (DG Environment 2008; EC 2011).
Within Alp-Water-Scarce, four different Early Warning Systems were developed that address the specific needs of the particular Pilot Sites: In the Arly catchment (France), the early warning system aims at long-term water reconciliation; in Carinthia (Austria), the early warning system is dedicated to ensuring a sustainable drinking water supply; in the Piave catchment (Italy), it is intended to help prevent user conflicts between hydropower generation and agriculture; and in Slovenia, the system contributes to water-saving measures for agriculture.

CASE STUDY 1
Early Warning System for the Arly Catchment (Haute Savoie, France)
The Arly early warning system is based on the synergy between a monitoring network and a hydrological model simulating the water balance. The monitoring of hydro-meteorological variables (e.g., precipitation, discharge, and aquifer water levels) enables an estimation of the different variables in the water balance. Moreover, additional observation data (e.g., isotopic data) can be used in order to corroborate the simulated flow paths and residence times. This contributes to an improved understanding of the hydrosystem's functioning, resulting in a reliable, consistent, and well-constrained representation. Anthropogenic water use is also well-observed in the catchment area. The spatial location and temporal evolution of withdrawals for various water uses (e.g., drinking water, agriculture, artificial snow production) were characterized. Two different hydrological models were implemented at the Arly catchment. First, GR4J, a simplified bucket model developed by the Cemagref (http://www.cemagref.fr) was used in a preliminary study in order to investigate the capacity of this type of representation and to simulate the seasonal hydrological variability. However, using such conceptual rainfall-runoff models whilst taking into account anthropogenic effects is challenging, and the description of hydrological processes is not suitable for short-term anticipation and long-term foresight (e.g., limited extrapolation capacity). In order to improve the descriptions of the various flow components, a process-based model was developed by the EDYTEM laboratory (http://edytem.univ-savoie.fr). This hydrological model of reasoned complexity is based on the concept of hydrological similarity (e.g., a topographic index used for lateral subsurface flow). Relatively simple representations were adopted for snow melting, evapotranspiration, surface runoff, and groundwater flow. The anthropogenic effects significantly affecting the water balance were accounted for using appropriate source/sink terms and by modifying the drainage network when necessary.
This preliminary version of the integrated model for the Arly Pilot Site can be used as a deci-

sion support tool for both short-term management and long-term planning. Given numerous sources of uncertainty, the computer model and the available observation data were complemented by system analysis mathematical and statistical tools for model calibration, sensitivity, and uncertainty analysis (i.e., variational approach and probabilistic methods). The motivation behind the development of this tool will ensure its continuous and sustainable improvement and sophistication in order to permit the exploration of alternative futures using climatic and anthropogenic scenarios regarding both water availability and demand.

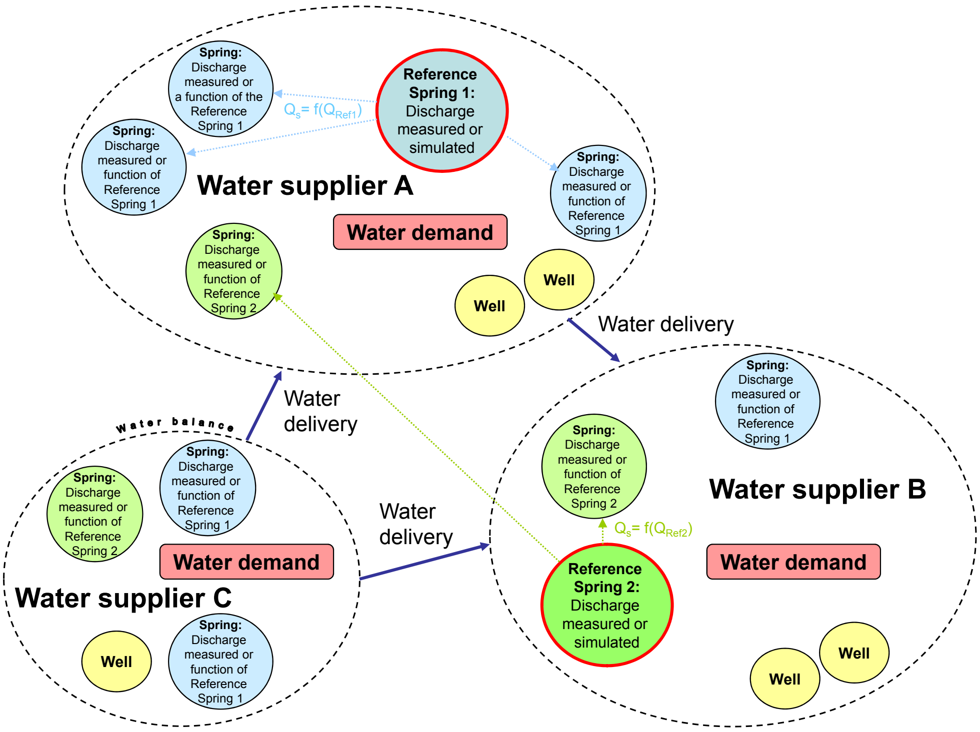
CASE STUDY 2

Early Warning System for Drinking Water Supply (Province of Carinthia, Austria)

The early warning system for the drinking water supply of the Province of Carinthia, Austria, can be separated into two parts:
1) a scenario catalogue for drought and water scarcity conditions, and
2) an estimation tool for drinking water resources.

1) The scenario catalogue for drought and water scarcity describes via diagrams the monthly relationship between the total amount of available water and the water demand in a water-supplying organisation. The generated diagrams show at which time of year water scarcity might occur. In this context, water scarcity is considered to be a shortage of drinking water supply. First, a database containing information about drinking water organisations, their water resources (springs, fonts, and supplies of water from other organisations), and their water demands (medium and peak water delivery to their consumers, water deliveries to other organisations) was compiled. For analysis of the water resources, 60 reference springs were selected. By cross-correlating, about 900 springs used for drinking water supply were assigned to appropriate reference springs. Using regression parameters, it was possible to estimate discharge from a non-reference spring using a measured or simulated reference spring discharge (Figure 13). To create the scenario catalogue for drought conditions, time series of discharge from 1970 – 2010 were simulated for every reference spring (using Bergström's HBV-Model, modified by the Technical University of Vienna, Austria; daily temperature and precipitation data were used). Statistical analyses of the simulated time series determined the return period of various low-flow conditions.

FIGURE 13:
Assessment of total water resources of water suppliers as the sum of discharges from their reference springs, springs (discharge calculated with a regression function from reference springs), wells, water deliveries, and water demand from their customers and from other water suppliers.



A "normal" state was defined as the average available water resources of an organisation; a "dry" state was defined as the minimum available resources with a return period of approximately 10 years; and a "very dry" state was defined as the minimum available resources with a return period of about 50 years.
For organisations with sufficient data, the monthly available resources of all springs, fonts, and deliveries from other organisations were summarized and displayed in the following diagram (Figure 14). The background colours show the medium (border orange to yellow) and peak demand (border yellow to green) of the organisation.

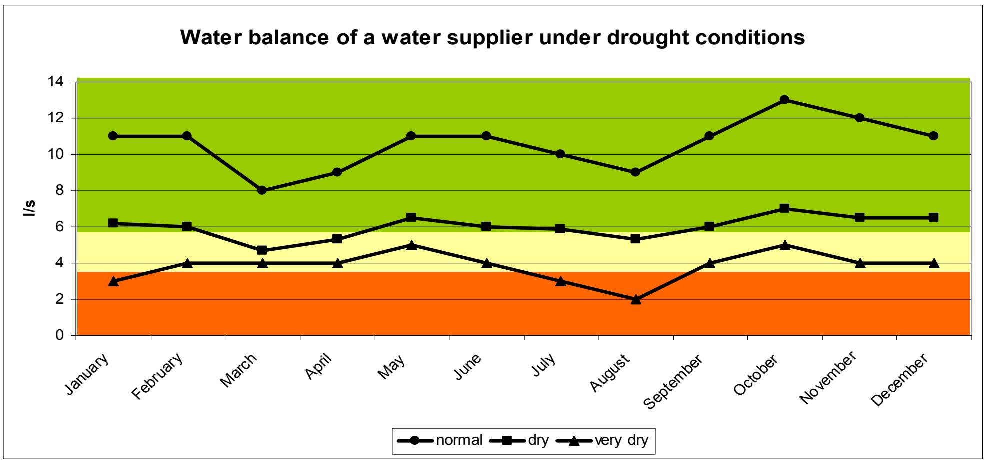
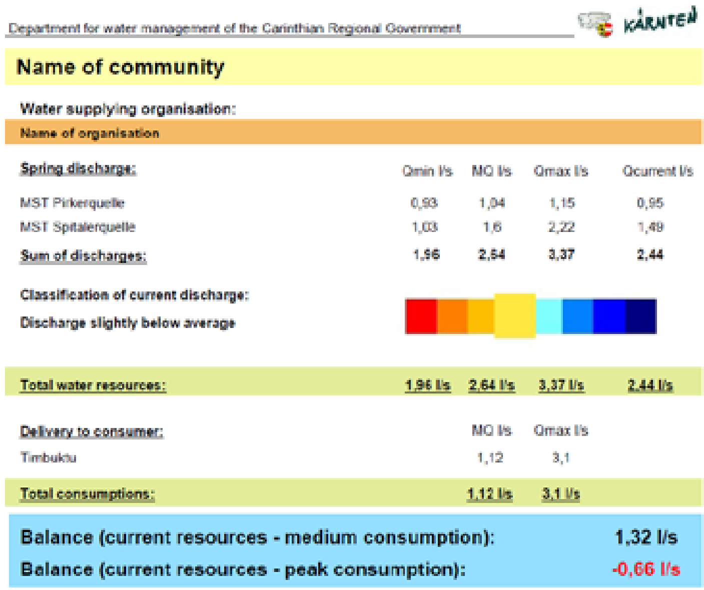


FIGURE 14:
Monthly water resources under varying conditions and medium and peak water demands of a water supply organisation. The "normal" curve stays in the green field, i.e., under normal weather conditions all demands (medium and peak) can be met. The "dry" curve stays most of the year in the green field but lowers in March, April, and in August, signifying that peak consumption might not be met. The "very dry" curve illustrates very rare droughts; for January, July, and August even not the medium water demand can be supplied.

These diagrams were generated for water-supplying organisations with sufficient data on spring discharge and water demand.

2) In addition to the static diagrams of the scenario catalogue, a dynamic system for the estimation of actual and future water resources is available. It shows the actual relationship between the total amount of available water and the water demand for a water-supplying organisation.The assessment is depicted by a water management diagram and a hydrological classification system. In the classification system, the result is scaled into 8 classes on a bar from minimum to maximum discharge. The water management diagram displays the relationship between available water resources and the theoretically calculated water demand. Furthermore, a prediction tool based on "normal", "dry", and "very dry" weather scenarios (prediction lead time: 3 months) is implemented.
In addition to the diagram and the bar, the water management and the hydrological information can also be displayed in a map of all the communities in Carinthia. This provides a quick overview of the community-wide hydrological spring conditions and shows which parts of Carinthia are or will be affected by water scarcity.

Every month, a report (Figure 15) is created that can be sent to communities and water suppliers. In case of a potential shortage (undersupply), this allows communities and water suppliers to take the necessary actions in time. This early warning system was initially developed for communities with adequate data but can be extended to other communities in the future.



Department for water management of the Carinthian Regional Government — KÄRNTEN

Name of community

Water supplying organisation:
Name of organisation

Spring discharge:	Qmin l/s	MQ l/s	Qmax l/s	Qcurrent l/s
MST Pirkerquelle	0,93	1,04	1,15	0,95
MST Spitalerquelle	1,03	1,6	2,22	1,49
Sum of discharges:	**1,96**	**2,64**	**3,37**	**2,44**

Classification of current discharge:
Discharge slightly below average

Total water resources:	1,96 l/s	2,64 l/s	3,37 l/s	2,44 l/s

Delivery to consumer:	MQ l/s	Qmax l/s
Timbuktu	1,12	3,1
Total consumptions:	1,12 l/s	3,1 l/s

Balance (current resources - medium consumption): 1,32 l/s
Balance (current resources - peak consumption): -0,66 l/s

FIGURE 15:
Example of a report for water suppliers.

CASE STUDY 3

Early Warning System for the Piave Catchment (Province of Veneto, Italy)

In the Piave catchment, hydropower is generated by a reservoir power station in the mountains. The Regional Agency for Prevention and Protection of the Environment of Veneto, Italy, created an early warning system for water scarcity using a methodology that consists of the analysis of the main hydro-meteorological parameters in 9 Alpine sub-catchments of the Piave River. This early warning system is a multi-criteria method focusing on a statistical analysis that considers the last 25 hydrological years as a reference period. The "Water Scarcity Index" (WSI) is estimated by comparing the current situation with past flow statistics (e.g., quantiles).

With regard to discharges, the base flow of 9 natural sections from the start of the hydrological year (1 October 2010), the base flow at the current date, and finally the accumulated amount of discharges since 1 January 2011 are considered. For affluxes, the quantiles of the accumulated amount of precipitation since the start of the hydrological year and since 1 December 2010 are measured. The quantiles of temperature are calculated considering, both the average temperature since the start of the hydrological year (1 October) and the average temperature since 1 March. In addition, the amount of snow is taken into account, both the snow depth and the accumulated amount of fresh snow since the start of the winter. A further parameter that may be included is total radiation (Figure 16). Recent years have shown a high frequency of long sunny periods in spring, with consequently fast snowmelts, which is why it may be useful to also calculate the quantiles of total radiation. All of these parameters are referred to the 9 mountain catchments, where discharges are evaluated.

The variables can be weighted, e.g., the amount of snow given more weight than solar radiation. The quantiles are then summed up to obtain the WSI. The calculation of the WSI for the current hydrological year automatically calculates the WSI for past hydrological years (since 1990-1991) in comparison to the date in question. The evaluation of the WSI for past hydrological years permits a calibration of the weights. Empirical data for the actual state of water scarcity in the following summer then allows a check on the reliability of the previously calculated WSI.

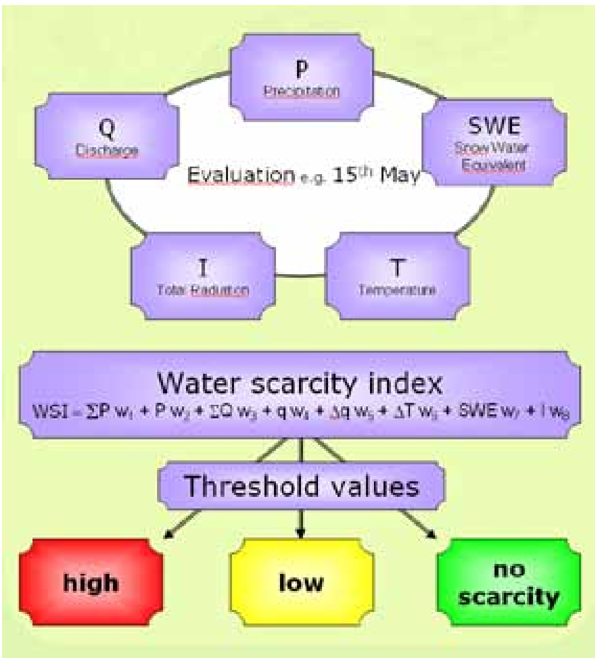


FIGURE 16: The early warning system for the Piave catchment.

CASE STUDY 4

Optimizing Irrigation – an Early Warning System for Agriculture in Slovenia

In northeastern Slovenia, plant irrigation is a necessary procedure in agriculture, as it ensures greater yield and higher quality in times of drought. The amount of additional water required depends on the plants cultivated but also on climate and soil conditions. In order to optimize the amount of water used for irrigation, a short-term early warning system for agriculture was developed for the Pilot Sites of Dravsko Polje and Ptuj Polje in Slovenia. This early warning system was based on the forecast of the quantity of water and the timing of its application to various crops using the IRRFIB (Irrigation Forecast Model in Slovenia; Sušnik A 2005) system (Figure 17), which takes precipitation data and evapotranspiration data for different crops as input indicators. Supplementary data relating to soil capacity and soil moisture in the zone with plant-available water is also included. For this purpose, daily data on plant-available water is recorded. During the vegetation period, the phenological phases of selected vegetable plants are also considered. The output of the model is the actual quantity of water in the soil versus the needs of different plants. The weather forecast is also taken into account, which generates precise data and recommendations regarding irrigation needs for the following four days. This information is available online.

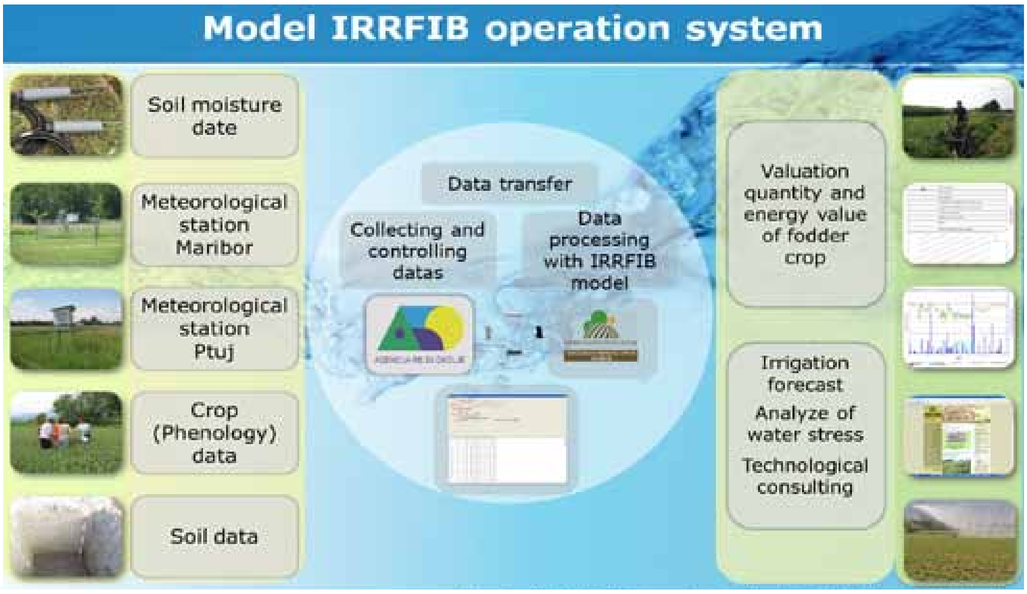


FIGURE 17:
The early warning system for agriculture in Slovenia.

RECOMMENDATIONS

- The terms “drought” and “water scarcity” should be defined, taking into account local/regional characteristics. A common understanding of these terms would improve the effectiveness of implementations of necessary measures.
- The establishment of early warning systems for water scarcity should be explicitly included in national/European legislation.
- The operation of early warning systems should be the responsibility of local/regional public authorities.
- The parties responsible for the implementation and operation of early warning systems should be clarified:
  - ✔ Who provides the necessary data?
  - ✔ Who guarantees the quality of the data used?
  - ✔ Who is responsible for maintaining the data?
  - ✔ Who is responsible for informing other stakeholders and the public?
- Early warning systems should be adapted to local/regional needs, ideally including those of the various users.
- Simulation models should be used in order to increase prediction lead time and reduce uncertainty.
- Long-term partnerships should be established with experts (including public and private consultants).

5.1.2 Implementation of Short-Term Crisis Management

Relevance and Case Study

Forecasting periods of water scarcity or drought with the help of early warning systems necessarily involves accounting for existing administrative or governmental regulations that determine the measures required to address these phenomena. The fast and efficient implementation of actions to prevent a crisis or to mitigate its effects is essential, and the cooperation of all parties concerned is crucial. All of the countries involved in Alp-Water-Scarce (Austria, France, Italy, Slovenia, and Switzerland) have established procedures to be implemented in the case of a crisis. However, the existing measures and frameworks need to be revised in order to deal with the impacts of climate change in some regions of the Alps that might involve longer and more frequent periods of water shortage.

CASE STUDY

The *Comiteé de Sécheresse* or Drought Committee in France: Example Savoy

During the summer of 2003, in 77 departments of France (out of a total of 101) measures were initiated by the prefects (NUTS 3 level) in order to limit water usage. This short-term crisis management, also in existence in the department of Savoy, seeks to preserve water resources during low-flow seasons and is based on a "framework law" ***(arrêté cadre)*** adopted by the prefect of the department.

The ***arrêté cadre*** specifies the hydrological warning levels beyond which measures must be taken, maintaining equity between agricultural, domestic, and industrial water use for the various water catchments and sub-catchments. To quantify the water level of rivers, hydrometric stations managed by the state are installed at the principal rivers in the department. The observations collected at these stations serve as a reference to determine whether warning levels have been reached.

In addition, other indicators (weather reports, water levels in drinking water reservoirs, hydroelectric dams, etc.) help to clarify the situation. If the situation is critical, all these indicators are presented at the Drought Committee ***(Comité sécheresse)*** convened by the prefect of the department. The Drought Committee includes many institutional and private water related actors; for example, in Savoy: the Department of Territories Agency (Direction Départementale des Territoires), the Civil Defence Agency ***(Direction de la Protection Civile),*** the Local Government of Savoy (Conseil Général de la Savoie), the Water and Aquatic Environments National Office ***(Office National de l'Eau et des Milieux Aquatiques),*** France Electricity ***(Electricité de France),*** drinking water associations, representatives of municipalities, and farming, fishing, and environmental protection associations.

During periods of drought, meetings take place at which each member of the committee presents indicators and reports to quantify the water level; e.g., the local government of Savoy would present the spring discharge measured by the monitoring network of the department, which is mandatory for local governments. Its implementation reflects acknowledgement of the need to better monitor water resources in order to anticipate potential crises.

The set of indicators and reports presented to the Drought Committee allows characterization of the hydrological situation at one of four levels: (1) awareness level, (2) alert level, (3) crisis level, or (4) reinforced crisis level. Depending on the situation, the prefect determines mitigation measures to be imposed on water users through a drought "local law" (arrêté préfectoral):

- **awareness level:** for example, publication of press releases to remind the public of the need to use water prudently;
- **alert level:** e.g., prohibitions against washing cars, filling private swimming pools, and watering lawns, public parks, private gardens, or sports facilities of any kind during the day; limitations on water usage for agriculture;
- **crisis level** (in addition to the restrictions mentioned in the previous level): e.g., closing public fountains, prohibitions against street cleaning and the use of water for agriculture during the day;
- **reinforced crisis level (**in addition to the restrictions mentioned in the previous level): e.g., requisition of available water supplies for drinking water, prohibition against water use for agriculture.

Each of these measures must be communicated to the public.

In Savoy, the use of water had to be limited by the Drought Committee for six years (starting in 2003), due to a significant rainfall deficit. Although these "local laws" for crisis management are theoretically dedicated to exceptional climatic events, they have now become a common tool for managing water resources. The indicators that are presently used to inform the Drought Committee only allow measures for short-term crisis management. Taking into account recent developments regarding the frequency of water shortages, new measures will be implemented in Savoy: the collection of data will be intensified, and modelling activities will be put into place to anticipate crises in the long-term. Furthermore, the work of the Drought Committee must also focus on technical solutions to overcome water shortages, such as leakage reduction, the search for new water resources, and the streamlining of needs, interconnected networks, and storage capacities.

RECOMMENDATIONS

- Emergency plans should be adapted to deal with longer and more frequent periods of water shortage.
- Available tools should be revised and adapted to establish appropriate measures under changing conditions.
- The short-term crisis management approach should be reoriented towards the implementation of long-term, anticipatory water management.
- A clear and precise information transfer policy should be implemented.
- The necessary administrative structures should be established that support long-term integrated water resources management in order to avoid periods of water scarcity.

5.2 Long-Term Measures

5.2.1 Securing Future Water Demand

Relevance and Case Studies

The main aim of sustainable water management is the protection of water resources for the future. Amongst others, the following two questions must be taken into account:
1. How will water resources evolve in the future, considering the impacts of climate change?
2. How will water resource demand evolve in the future?
An estimation of these two variables will enable water managers to take the necessary measures to meet water demand whilst preserving the resource.

CASE STUDY 1

Past and Future Groundwater Recharge and Runoff at the Austrian Pilot Sites

At the Austrian Pilot Sites, the long-term development of water resources was analysed by measurement of the variables "groundwater recharge" and "runoff". Groundwater recharge was analysed at Pilot Sites with porous aquifers in flatlands and valleys (Jauntal and Gurktal in Carinthia) where the water storage dynamics are primarily controlled by vertical infiltration according to the actual amount of precipitation. In Pilot Sites located in Alpine valleys and catchments (Karawanke, Koralpe, and Styrian Basin), where lateral flow processes are dominant, the analysis mainly focused on the runoff at the catchment outlet, i.e., at the location of a stream gauge. Continuous records of runoff data in Austria started in the early 1950s. In general, groundwater recharge cannot be measured at the regional scale. Although point data from a lysimeter station located at the Styrian Basin Pilot Site are available, they cannot be transposed to other regions and thus cannot be used in a regional context; however, they permit study of the processes in more detail.

For a prolongation of the groundwater recharge, data from HISTALP (www.zamg.ac.at/histalp) was used as follows: the actual/real evapotranspiration (ET) was calculated using the formula developed by Turc (1954). The formula is valid on an annual basis. Based on the overall water balance, groundwater recharge and runoff was estimated from the precipitation minus the calculated actual/real ET. However, the coefficients of the Turc formula must be adjusted to the local situation regarding actual/real ET from vegetation and soils. For this purpose, the Turc estimations were adjusted to the observed runoff data in the gauged catchments and, in the basins with porous aquifers, the groundwater recharge obtained by a spatially distributed hydrological model. Figure 18 shows the results from four Austrian Pilot Sites, indicating a negative trend evident from the beginning of the 20th century. Goodness of fit to the observed runoff is high in the catchments, so the general trend is assumed to be reliably represented by the Turc formula.

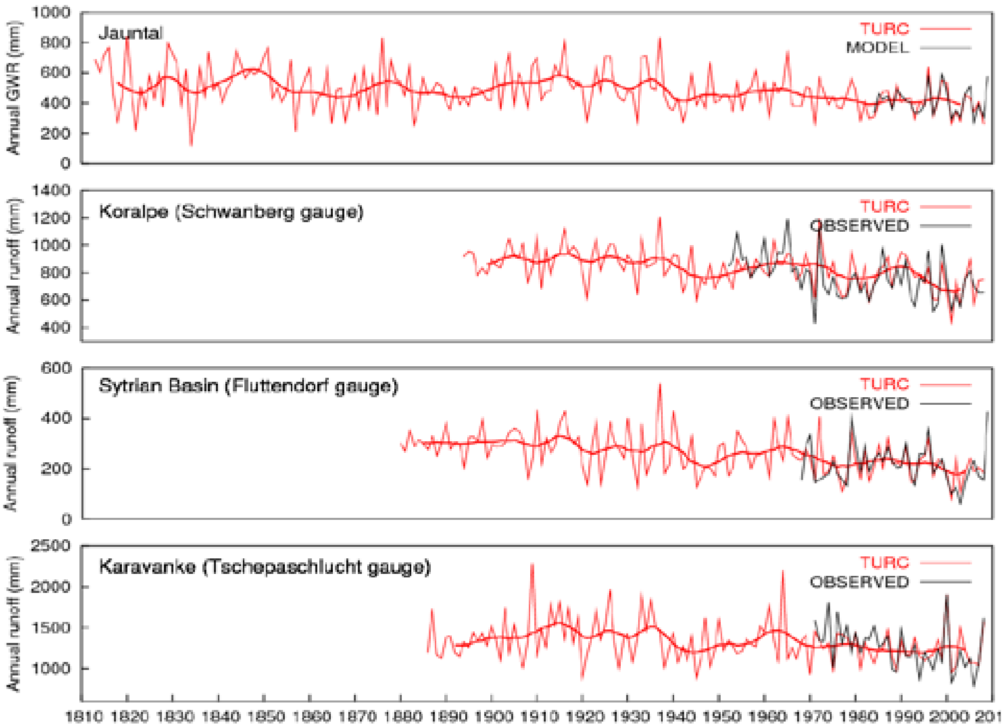


FIGURE 18: Time series of annual runoff and groundwater recharge (mm/y) estimated via the Turc formula for the actual ET and the general water balance equation, based on the HISTALP data available in the corresponding region.

Having set up and calibrated the models to historical data for the different Pilot Sites and catchments, scenarios were simulated to quantify the impact of a possible future change in climatic conditions on water resources. It must be noted that these scenarios cannot be interpreted as projections into the future, but as “what if” scenarios generated by altering the model input air temperature (T), precipitation (P), and potential evapotranspiration (PET) to quantify the sensitivity of the hydrological system to these variables. The scenarios were based on the “Delta-Change” approach (see scenario guidelines, Saulnier et al. 2011): A reference period was selected (here, the decade from 1999 to 2010) and various assumptions regarding expected climate change signals were made.

– Selection of a Delta-Change of temperature: In this case study, an extrapolation of air temperature changes over the last 50 years based on the HISTALP time series (including a seasonal variation in change) was made. Changes in PET were derived from the air temperature change via regression analyses (Saulnier et al. 2011)
– A second scenario was generated using the assumptions in Scenario 1 but including a change in annual precipitation. At most of the Austrian Pilot Sites, a reduction in annual precipitation can be observed in the HISTALP data. However, variability of precipitation is very high, and at most of the HISTALP stations this trend is not significant. Furthermore, the uncertainty of precipitation changes derived from climate models is very large and therefore not used here. As an example for a further “what-if” scenario, at the Austrian pilot sites a 5% decrease in precipitation, equally distributed over the whole year, was chosen (Saulnier et al. 2011).

Figure 19 shows as an example the historical changes in temperature (above) and PET derived from the monthly temperatures (below) from the Bad Gleichenberg HISTALP station in the Styrian Basin. The plot shows monthly Delta-values, i.e., the average for each month from 1999 to 2009 minus the average from 1960 to 1970 (change over five decades). For scenario generation, this delta change was added to or subtracted from the daily time series in the reference period. The hydrological model was then driven by these changed time series. This "what-if" scenario can be interpreted as a linear extrapolation of the historical change into the future and therefore corresponds to a possible change 50 years from now, i.e., 2041-2050. According to this assumption, the mean annual temperature rise in the Styrian Basin over the next 50 years is expected to be 1.1°C. This leads to a mean annual change in the PET of 5.1 mm per month.

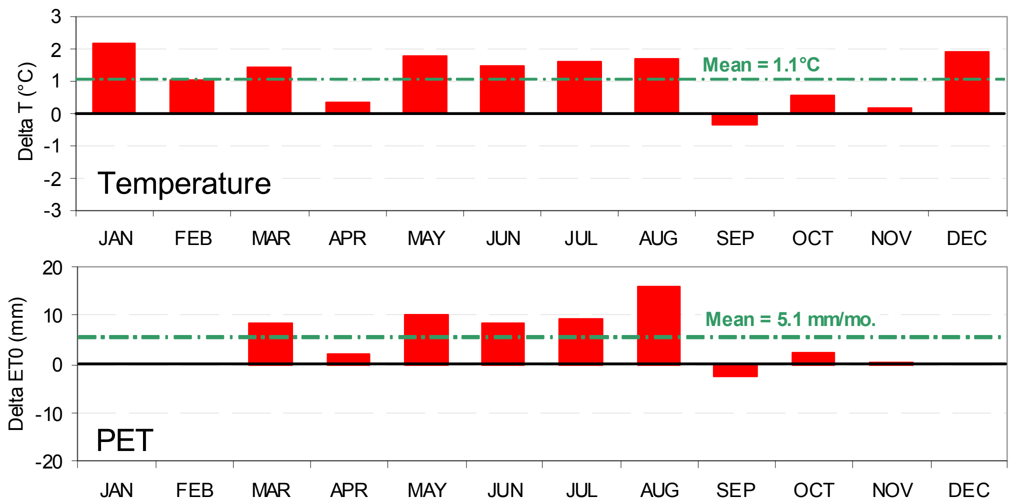


FIGURE 19: Historical change of temperature (above) and PET (below) on a monthly basis from the HISTALP data (last 50 years), which (as a "what-if" scenario) is extrapolated into the future (corresponds to a change 50 years from now, i.e., 2041-2050).

Figure 20 shows the simulated scenarios for mean monthly groundwater flow (10-year average) in the catchment of the Fluttendorf gauge located in the Styrian Basin. Groundwater flow according to the different scenarios is diminishing compared to the reference period (1999-2008). In Scenario 1 (red line), only the impact of air temperature (and PET) rise can be seen. Runoff increases in January and February due to an earlier snow melt. A further 5% reduction in precipitation in addition to the increase in air temperature from Scenario 1 (i.e., superposition of possible temperature and precipitation changes) leads to a relatively strong additional reduction in groundwater flow (Scenario 2). This is due to the non-linearity in the hydrological system, which is represented in the model.

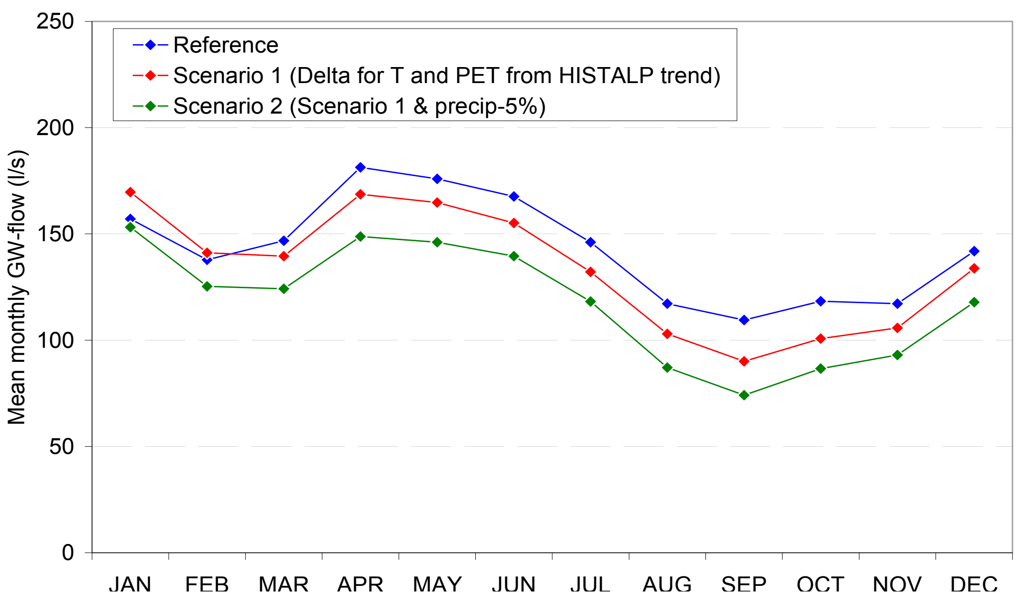


FIGURE 20: Scenarios of mean monthly groundwater flow (10-year average) in the catchment of the Fluttendorf gauge in the Styrian Basin. The reference period is 1999-2008.

CASE STUDY 2

Water Demand Outlook for the Province of Styria, Austria (2009 – 2050)

For the Austrian Pilot Sites of Styrian Basin, Wechsel, and Koralm, water demand was calculated for districts partly or completely included in the investigation area for the year 2050. The calculation was based on information collected from the "Water Supply Plan of the Province of Styria" (Benischke et al. 2002), the "Prognosis for the water demand" (Schippek-Erhart 2002), and the "Guideline for public water supply" (Be nischke et al. 2002), as well as a questionnaire survey from September 2009 and statistical data from Statistics Austria and the Austrian Conference for Spatial Planning.

In order to provide a good preview of future water demand, all important sectors with higher water demands were included in the prognosis: communal usage, tourism, trade and industry, and agriculture (divided into irrigation and cattle water supply).

Communal demand: Demand for private households, local trade, and small touristic facilities.

Tourism: Few water providers could give estimations of the water demand from tourism. Where data was available, the number of overnight stays was used to adjust the calculations.

Trade and Industry: Water demand for industrial production is only partly met by the central drinking water suppliers. Industries with a very large water demand generally have their own extracting plants. Data on water demand for trade has been collected from water suppliers.

Agriculture (irrigation and cattle water supply): In 1999, a census of livestock was conducted in the Province of Styria. Since the amount of livestock has not changed over the past 30 years, no changes were made for the future prognosis.

Based on the results of a study conducted by Kaiser & Mach (2004), an estimation of water demand for irrigation was calculated for: fruits, corn, vegetables, vineyards, and greenhouse cultivations.

Figure 21 (left) shows the total water demand for the most important sectors for 2009. Agriculture created the highest water demand (47%), followed by demand from municipalities (38%). Tourism and industry were of less importance in the area as a whole, but there are extreme regional differences. The water demand from 2009 was taken as a basis for extrapolation to the year 2050 (Figure 21, right). In this extrapolation, estimations of demographic development and climatic situation were included. Although regional differences in the development of water use can be observed, the division of demand between sectors does not change significantly between 2009 and 2050 (Figure 21).

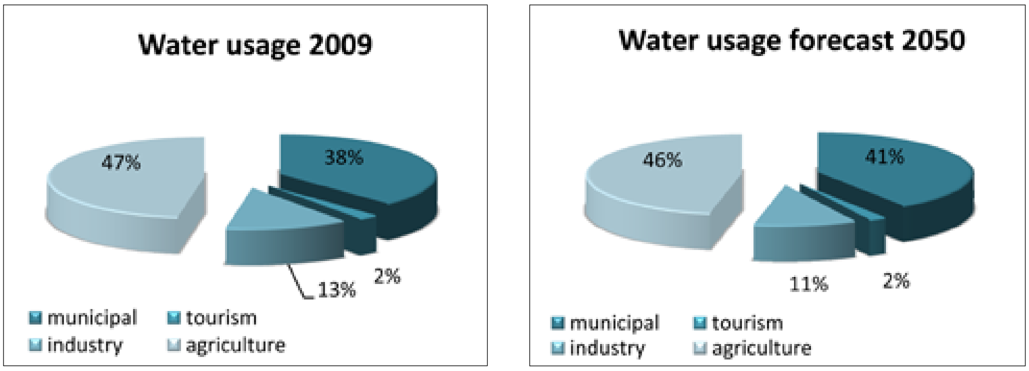
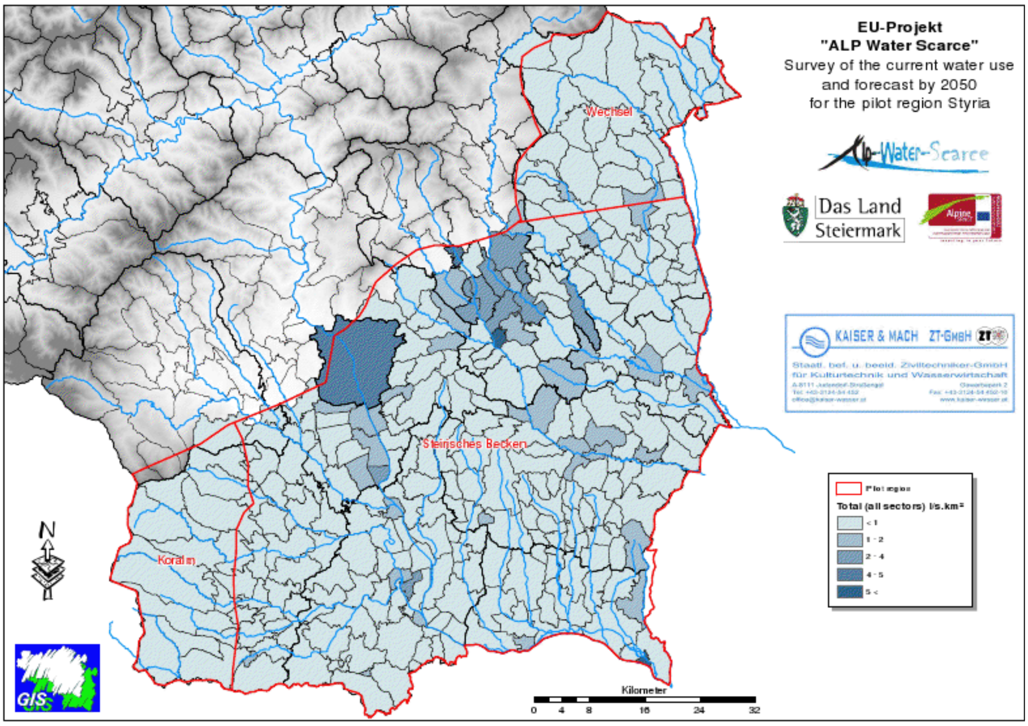


FIGURE 21:
Classification of actual (2009) and forecasted (2050) water demand.

The maps in Figure 22 illustrate the sum of all water uses in the communities of the Styrian Pilot Sites. The values are normalized to the area of the communities and are therefore expressed in l/s km². It should be noted that some areas (e.g., the city of Graz) receive water from other regions. The estimated forecast shows that areas with the highest water demand at present should also have the highest values in 2050.

The demand for water is satisfied by long-distance pipelines as well as local artificial recharge installations (for the city of Graz). In this way, there is assurance that – in the sense of the European Water Framework Directive – the overuse of groundwater can be avoided also in the future.

Water demand 2009



Water demand prognosis 2050

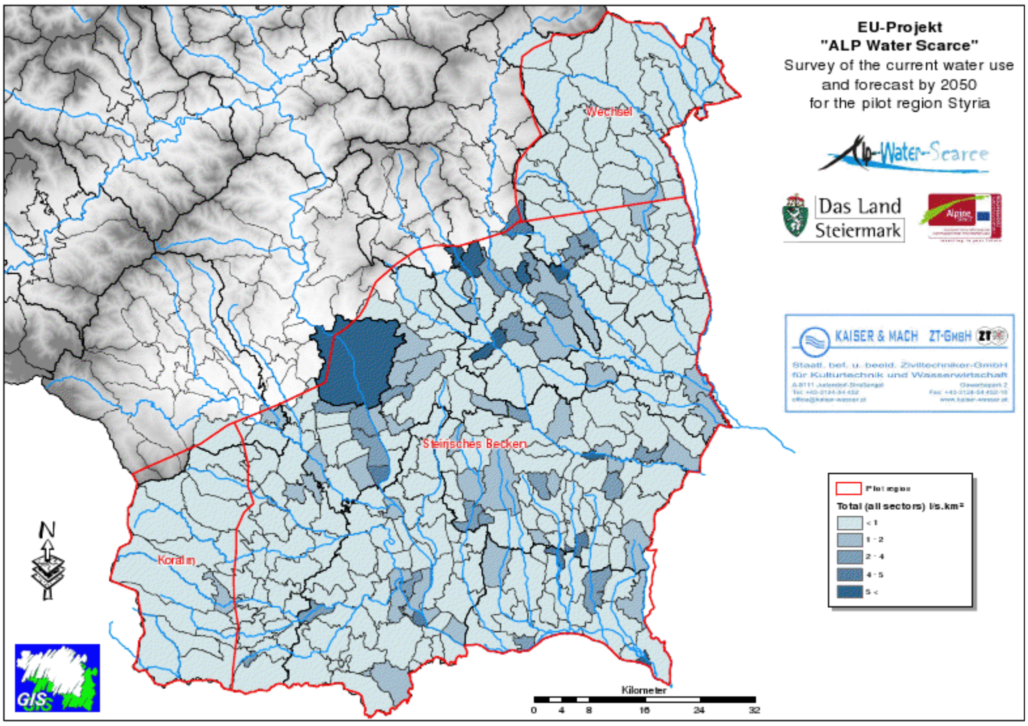


FIGURE 22:
Total water demand in l/s km² in 2009 and forecast for 2050 for the Pilot Sites in Styria, Austria.

RECOMMENDATIONS

- Data sharing and integration should be promoted (across different sectors, regions, etc.).
- Actual water demands should be monitored and an analysis of past water demands made (including information on demand seasonality, socio-economic data, etc.).
- The development of future scenarios of the evolution of water resources taking into account the impacts of climate change should be considered.
- Future changes in the water demands of the most important water users should be estimated.
- Measures to adapt water management strategies should be implemented to account for changing scenarios of water availability (e.g., developing long-term structural changes for water saving in agriculture).
- The planning of artificial recharge installations under favorable hydrogeological conditions should be considered.

5.2.2 Promoting Consolidation to Avoid Resource User Conflicts

Relevance and Case Studies

An increase in the duration of periods of water scarcity will intensify cross-sectoral water competition in the Alps. Increased demand for agricultural irrigation could reduce water availability for other sectors, such as drinking water, energy production, etc., and vice versa (Moser et al. 2011). Increased water demand by tourism in summer will compete with agriculture and demands for hydropower generation (EEA 2009). Decreasing water resources for hydropower generation may conflict with increasing demand for electricity for indoor cooling in summer (Prettenthaler et al. 2007). Furthermore, these pressures and the resulting ecological stresses on aquatic ecosystems ("optimal ecological discharge") must be taken into account.

The prevention of conflicts before they start should be the primary objective. A series of case studies demonstrates how consensus can be reached between industrial and nature conservation interests (Spöl, Switzerland, and Rotaliana plain, Italy), how different sectors must cooperate in reclaiming a certain resource (Piave catchment, Italy), and, importantly, the perspective of a public body (UNCEM Piedmont, Italy) facing increasing pressure from one sector for mountain water resources.

CASE STUDY 1

The Spöl Experimental Flood Program – a Compromise between River Ecology and Hydropower Generation

The Spöl River flows from the Livigno Reservoir on the Swiss/Italian border through the Swiss National Park in the canton of Graubunden, Switzerland. Through collaboration between the Engadiner Power Company and the Swiss National Park, an experimental flood program was initiated in 2000 to improve the ecological integrity of the river and of the fishery in particular. The flood program uses an adaptive management protocol that bases floods on water availability and research goals that change over time.

Figure 23 shows the flow regime prior to regulation, an example of the regulated flow before the flood program, and the actual floods each year after the flood program was initiated. The flood program started with a series of three floods, with the magnitude of each flood simulating flows in that respective season; essentially, two small floods were created, one each in spring and fall, bracketing a larger flood in the summer. After a number of years, the smaller floods were shown to have little impact on the ecology of the river and thus only larger floods were used. The number of floods was also reduced to 2 per year when water was available. These larger floods were used to mobilize bed sediments, alter channel morphology, and reduce fine particles that were clogging bed sediments. As shown in the graph, there were some years (e.g., 2002, 2003, and 2005) when a smaller flood was used or when only one flood was created. The extreme example is 2005, when there was sufficient water for only one small flood. After 2006, two large floods were implemented each year, as sufficient water was available. The most recent data suggests that the larger floods should be reduced in magnitude, but remain larger than the initial smaller floods, as they are now considered to be ecologically detrimental to the river and fishery. Researchers also used this flood experiment to simulate a drought year in 2010, by eliminating floods for one year and assessing the effects on the river ecology (these data are presently being evaluated). This long-term experimental study nicely demonstrates the power of an adaptive management protocol that incorporates water availability with river ecology. The flood program is viewed as a large-scale, long-term experiment in using flood flows under different scenarios of water availability to sustain the ecological integrity of a river.

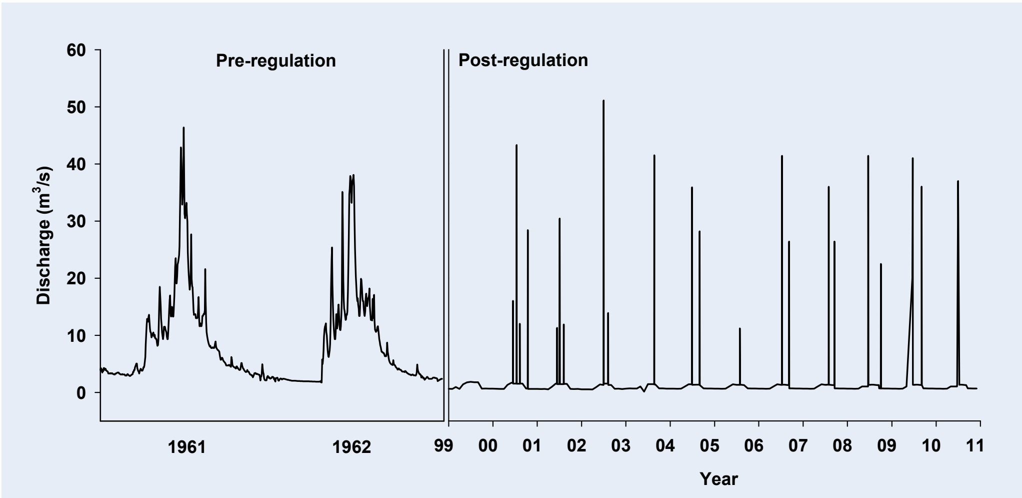


FIGURE 23:
Spöl experiment: Discharge before the regulation and after the regulation of the river.

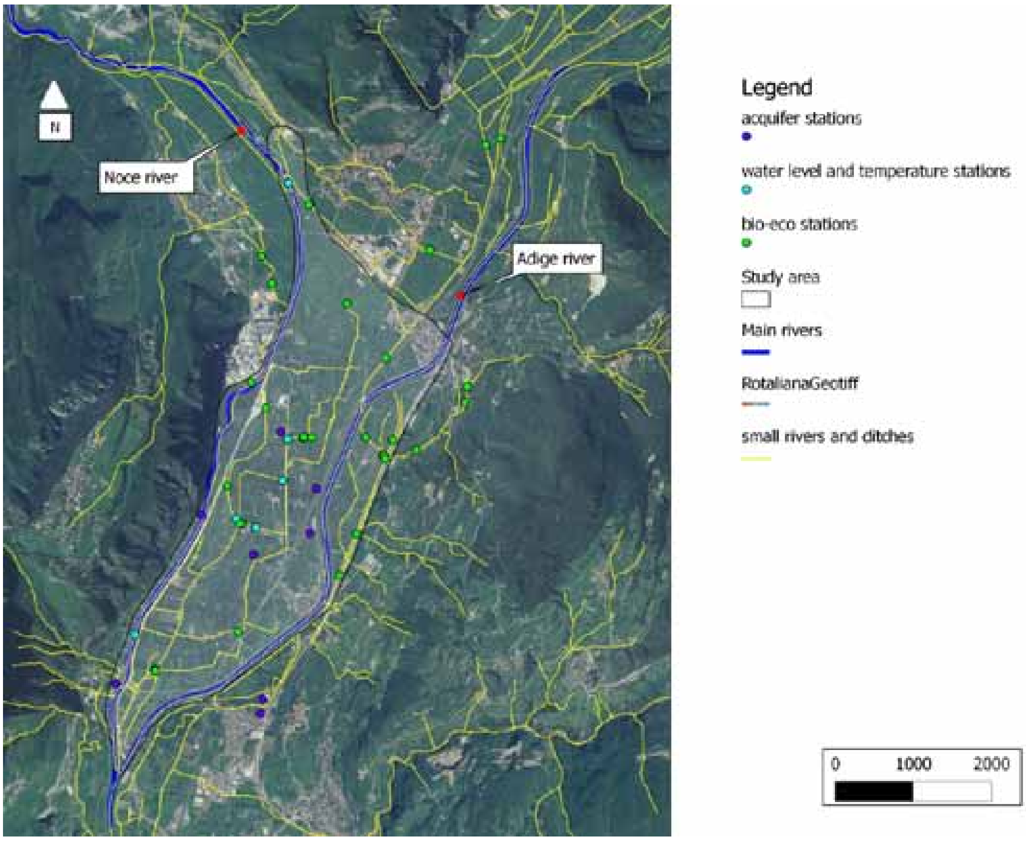
CASE STUDY 2
Re-use of an Agricultural Ditch Network

In Alpine countries, running water has been extensively tamed to better respond to human requirements; morphologies and hydrological and thermal regimes have been altered. Channels have been straightened and banked for flood protection, particularly in lowland areas, where the mild environmental conditions foster high biodiversity and ecological processes, consequently providing the most favourable conditions for agriculture. As a result, lowland freshwater habitats have been greatly diminished, with severe impacts on freshwater biodiversity and ecosystem processes. River reaches in these areas often suffer from strong flow regime alteration due to multiple water uses, with hydropower production frequently playing the most important role for relatively long sections characterized by the propagation of hydro- and thermopeaking waves.

The case study of the Rotaliana floodplain (Noce River system, Figure 24) has focused on the presence of an agricultural ditch network near a hydropeaking-regulated river reach, with the goal of assessing the potential of this typical combination for floodplain restoration in an Alpine valley floor.

The research idea is that re-using part of the hydropeaking water in the network of agricultural ditches can improve the ecosystem health of the river-floodplain system. An eco-hydraulic experimental research was carried out with the aim of analyzing the contribution of a ditch network to floodplain biodiversity, and to assess its potential to mimic the multi-functional role of extinct natural wetlands through re-use of part of the excess water in the river reach associated with hydropeaking.

FIGURE 24: Rotaliana floodplain measuring network.



Conductivity, pH, dissolved oxygen, mean velocity, depth and width of the wet channel, distance from the source, and water temperature were measured. Species composition and relative abundance of macrophytes were recorded. Hydraulic characterization of the ditch network was performed by integrating historical topography data with recently collected data, together with information on ditches cover for roughness estimation. The network hydrodynamic response to different options of re-use of water from the nearby Noce River in the network was simulated using a 1D unsteady flow model supported by local hydraulic measurements. A simplified one-dimensional model for both surface-subsurface flow exchange and conservation of thermal energy was applied to quantify the lateral extent of the riparian region affected by hydropeaking oscillations. The discharge capacity of existing intake structures from the nearby river reach was quantified using direct flow measurements at some indicative sites, with the cooperation of personnel from local drainage boards

Hydraulic simulations indicate two markedly different scenarios dependent on the value of the discharge fed into the network from the adjacent river reach under hydropeaking conditions. A threshold discharge value of a few hundreds of litres per second indeed discriminates the possibility of affecting a large number of ditches with re-used water. Intakes larger than this value are needed to achieve broad ditch coverage with re-used water.

Important indicators to assess the restoration potential, such as hydraulic residence times in surface and subsurface water bodies, extension of terrestrial/aquatic ecotones, dilution rates, and variations in the ditches' thermal regimes can also be quantified by application of the surface-subsurface flow model.

The results indicate that a relatively small agricultural area can host a wide variety of potential freshwater habitats, represented by the irrigation ditch network. In semi-natural ditches where sufficient flow and constant water quantity was present, biodiversity reached interesting levels.

Along rivers crossing Alpine lowland agricultural areas, the possibility of attenuating hydropeaking waves by restoring water flow in nearby agricultural ditches appears to be a very promising way to enhance freshwater biodiversity through the restoration of a mosaic of

aquatic habitats on a small spatial scale. Such habitats may also act as proxies for natural wetlands if they are physically restored to a semi-natural condition.
The proposed approach also has good potential for recharging the floodplain groundwater, particularly in Piedmont Alpine areas with relatively high hydraulic conductivity where surface-subsurface water exchanges are primarily controlled by convection. Groundwater recharge is likely to be more effective for larger hydropeaking wave durations and for greater lengths of the total ditch network subjected to water re-use.

CASE STUDY 3
User Conflicts – Hydropower Generation and Agriculture in the Piave Catchment
At the Piave Pilot Site, hydropower generation and irrigation account for nearly 95% of the total withdrawals identified for the Pilot Site for which data has been collected. The main agriculture derivations in the catchment are located in Fener (16.2 m^3/s in winter and 35.8 m^3/s in summer), in Nervesa (18 m^3/s in winter, 32 m^3/s in summer), and in Soverzene (11.5 m^3/s in winter and 32 m^3/s in summer). The total withdrawal varies between 45.9 m^3/s in winter and 99.8 m^3/s in summer. Due to the water storage capacity of the artificial lakes (150x106 m^3), the deficit situation can be decreased. Nevertheless, the amount of water available for agriculture and hydropower generation is insufficient for at least 10 days almost every summer. The importance of the aforementioned artificial lakes (Figure 25) can be underscored by the fact that without them, 29 deficit years would have occurred over a period of 36 years (1926-27 to 1961-1962) (Dalla Valle & Saccardo 1996). With the existing artificial lakes, this estimated deficit was greatly diminished (to only 3 out of those 36 years). In any case, over the past 20 years, more than two situations of water scarcity were observed (i.e., 8 periods).
Since 2001, release of the optimal ecological discharge (OED) has been prescribed by the Basin Authorities (Autorità di Bacino 1998) in the Piave catchment, which has had greater consequences on hydroelectric production than on the availability of water for agriculture. The water released for agriculture is also used for hydroelectric production. This mainly affects the profits of the hydroelectric companies (because they have to produce energy also during times of lower demand and not only during the peaks) rather than the amount of energy produced. The power plant most affected is “Sospirolo”, which utilizes the water stored in Mis Lake, because the agricultural unions have the right to use the water since they participated in construction of the dam. The total hydroelectric water use corresponds to more than 400 MW of power; the power plants are often connected in series, thus the sum of water abstracted is highest also in summer (67%), but the real water consumption is due to agriculture. The only real water withdrawn due to hydroelectrical power for the Piave catchment is the 30 m^3/s (or more) transferred out of the catchment to the Livenza River. The abstraction of water in winter by the agricultural unions (29% of total winter usage) is due to the fact that in some channels, water is used not only for irrigation, but also for electric production and for supplying some cities with drinking water. Furthermore, the release of the optimal ecological discharge can be seen as a “new” utilization of the water in the catchment that has priority over all other water usages. Since the total water availability is constant, the amount of withdrawal must be reduced. This is, of course, also the case for maximum discharge levels. This reduction has already been implemented for hydropower companies, but not yet for agriculture unions.
To solve this problem of user conflict between hydropower generation, optimal ecological discharge, and agriculture, a first step could be to decrease the mean and maximum discharge related to agriculture. This decrease needs to equal the optimal ecological discharge.
A second step could be a change in irrigation systems, adopting more efficient methods (i.e., drip irrigation).
In a third step, the storage capacity of the existing lakes could be increased (e.g., reestablishing the original capacities). In lowland areas, losses in irrigation channels could also be reduced.
A fourth step might be the utilization of exhausted quarries as artificial reservoirs, creating a small degree of freedom between the hydroelectric system and the agriculture system.

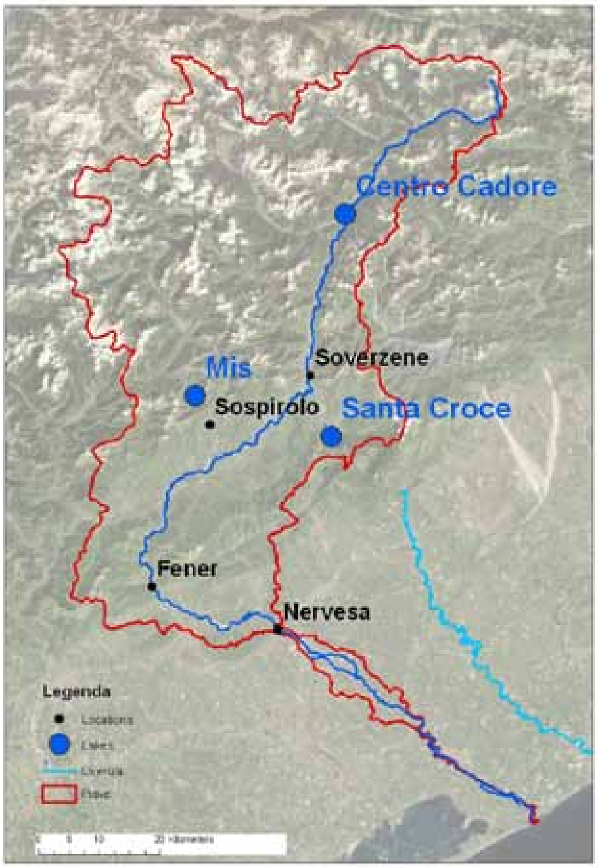


FIGURE 25:
Location of the three biggest lakes in the Piave Pilot Site.

CASE STUDY 4

Water Sharing Issues in Piedmont, Italy

The Sesia river basin and the situation in Piedmont, Italy

This Pilot Site was chosen for the Alp-Water-Scarce project because the characteristics of this area represent to a certain extent the situation of Piedmont and in particular its mountain areas. Data collected in the project showed that issues of water management are not directly linked to water scarcity but rather to conflicts in its usage: 28 l/s km^2 of medium rate flow can meet the water demand for all the different uses in this area, given the low number of inhabitants (34,000 in an area of 760 km^2). This situation results from the large number of tributaries and streams that increase the volume of the Sesia River and by the water flowing from glaciers situated on the southern part of the Monte Rosa. This is underscored by the fact that the glaciers of Valsesia have significantly diminished: about 53% (from 8.7 km^2 to 4.1 km^2) from 1850 to 2000.

Issues concerning water management in this particular region generally concern water use by hydropower companies: there are a large number of powerplants, with a yearly production of 6354 GW (approx. 1 billion Euros, of which 16 million return to the territory). The hydroelectric production in Piedmont is guaranteed by over 800 derivations from natural water courses, hundreds of systems located on well-water canals, and some dozen systems installed on the main ducts of important waterworks. There are 70 systems classified as big derivations (power greater or equal to 3 MW).

In 2007, 475 hydroelectric systems were operating in Piedmont, generating 3464 MW. In the same year, the gross production was 6254 GW. The annual average production from 1997 to 2007 was 6000 GW (the production is strongly influenced by the quantity of precipitation). The province of Cuneo is the principal area of hydroelectric production, home to systems producing 47% of the efficient gross power, followed by the province of Turin with 27% and VCO (Verbano–Cusio–Ossola) with 23%.

Conflicts

The installation of large hydropower plants in the Alpine Piedmontese valleys is still ongoing. Many voices in the territory complain about the situation that in most cases guarantees only small annual contributions to municipalities and that is not a real source of development for large mountain territories. The Mountain Community, in collaboration with the province of Piedmont can coordinate new operations in the hydroelectric field (mainly "minihydro"), resolving conflicting interests regarding water use (for example, reducing the possible negative impacts of hydroelectric stations on tourism), and can block new attempts at exploitation.

Possible solutions and proposals

Naturally, one of the main challenges in this situation is trying to set up usage rules in consideration of the different needs (management and economic points of view). To this end, a "Strategic Plan for Water Management of the Sesia River basin" was drafted in collaboration with the Valsesia Mountain Community, the local authority with representatives from the 28 municipalities of Valsesia. The different uses of the Sesia River basin were analysed. The goals of this plan are to increase hydropower generation and to protect the environment and the landscape of the valley (the most important factor behind tourist interest), but at the same time to create economic benefits for local development in this mountain area. On 26 June, the presidents of 22 Piedmontese Mountain Communities and the mayors of the mountain municipalities of Piedmont organised Diga Day (Dam day), promoted by Uncem, at the Entracque dam. This was an occasion to emphasise the importance of municipalities and mountain communities taking part in competitions for the reassignments of hydroelectric concessions, or (as took place in the Mountain Community Valleys Grana and Maira in Acceglio) being directly involved in the establishment of new systems, tenable and appropriate to the territory, which produce energy for the disposal of the entire community and also contribute a percentage of the profits to the social and economic development of the mountain territory.

RECOMMENDATIONS

- Integrated planning for the sustainable use of water resources should be a priority.
- The value of ecosystem services should be recognised in determining the balance between economy and ecology.
- The multifunctional use of existing water storage capacities should be promoted.
- The interconnection mechanisms of existing networks should be improved to increase the resilience of available water resources.
- The evolution of water resources should be observed (monitoring and modelling).
- Measures should be implemented that are adapted to regional/sectoral needs. These measures could include technical solutions, the temporary prioritising of one sector over another, or the adaptation of practices (e.g., for agricultural land use and livestock) to a lower water supply requirement level. All measures need strong and clear political support.
- A clear set of regulations and cooperative agreements is necessary (regionally modified when required).
- The efficiency of water usage by the different sectors should be increased (e.g., drip irrigation for agriculture, increasing the storage capacity of existing dams, reducing unnecessary losses).

5.2.3 Technical Solutions

Relevance and Case Study

The previous chapters offer suggestions to mitigate periods of water scarcity. Most of these measures can be supported by technical solutions, such as increasing the efficiency of the supply network (minimizing water losses); optimizing irrigation techniques; restoring floodplain ecosystems for improving water yield; increasing infiltration capacity by increasing the complexity of surface water networks; increasing the efficiency of water use for industrial production; infiltration rather than deviation of surface water; and artificial groundwater recharge.

CASE STUDY

Artificial Groundwater Recharge as a Mitigation Measure to Prevent Water Scarcity for the Drinking Water Supply

In some Alpine areas, increasing demand for water combined with reduced groundwater recharge has led to the use of surface water for artificially recharging groundwater systems, with the aim of storing water underground in times of water surplus to augment the possibility of groundwater withdrawal in times of shortage. Surface water is directed underground by infiltrating it into infiltration ponds or ditches or directly into infiltration wells. This method is approved in Alpine valleys with highly permeable gravel fillings and has been used with success for two drinking water supplies from wells of the city of Graz in the Mur valley (Styrian Basin Pilot Site, Austria).

In mountainous areas, the possibilities are more limited and depend mainly on the hydrogeological conditions. As springs are primarily used for the drinking water supply, the possibilities to infiltrate surface water in the catchment area are often limited, and parameters such as the discharge of the usable creeks, the permeability of the soils and rocks, and in many cases the recharge area of the springs must be determined.

The following conditions must be checked in detail:

- Quantity of source water available (taking into account the national water laws concerning residual flow or ecological flow)
- Quality of source water and pollution sources in the catchment
- Determination of the recharge area of the spring (mainly applicable in karstic areas and only possible on the basis of intensive hydro-geological investigations such as isotope studies, water balance, and tracing experiments)
- Sediment load of source water (risk of clogging for the infiltration ponds or ditches)
- Residence time of infiltrated water during the underground passage to the spring to avoid bacteriological contamination (different legislations exist in the Alpine countries; in Austria, the limit is 60 days)
- Underground storage capacity must be available
- Sufficiently high permeability of the unsaturated and saturated zone
- Depth of the groundwater table must be determined to avoid water logging on the surface
- The total hydrogeology of the aquifer must be investigated and understood before the establishment of the artificial groundwater recharge is implemented
- Protection zones and measures must be established for the catchment area in order to avoid contamination
- The type of water injection must be topographically clarified
- Intensive monitoring of water quantity, quality, and sediment load as an early warning system to avoid short-term contamination

In consideration of these factors, the methodology of artificial groundwater recharge can be considered as a possible method to avoid water shortages for the drinking water supply in periods of water shortage, but it must be emphasised that the possibilities of its implementation depend to a great extent on the local meteorological, hydrological, and hydro-geological conditions.

RECOMMENDATIONS

- The storage capacity of dams and drinking water reservoirs should be increased where compatible with ecological aspects.
- The efficiency of existing infrastructure should be enhanced.
- Water-saving technologies should be prioritized (e.g., drip irrigation for agriculture, reduction of leaks and line losses).
- Plant maintenance and line flushing should be adapted to changing conditions.
- Water treatment (drinking water supply) should be adapted to expected changes in water quality.
- Opportunities for water re-use should be considered and optimized.
- Water supply networks should be extended.

5.2.4 Interregional and Transboundary Cooperation to Secure Water Resources

Relevance and Case Studies

The pressure on transboundary water resources can lead to potential conflicts between users and states sharing the same springs or groundwater basins (UNDP http://europeandcis.undp.org/environment/wg/show/FA499AD7-F203-1EE9-BF1DD1F9F83C486F). For Europe, agreements for such transboundary water management exist for the main river basins of the Danube, Elbe, Meuse, Mosel, Oder, and Rhine, which of course also affect the Alps, since they are the origin of some of these river systems. In addition to these agreements, there are also other initiatives that seek to share common (transboundary or interregional) water resources.

CASE STUDY 1

Karavanke/Karawanken Transboundary Groundwater Management

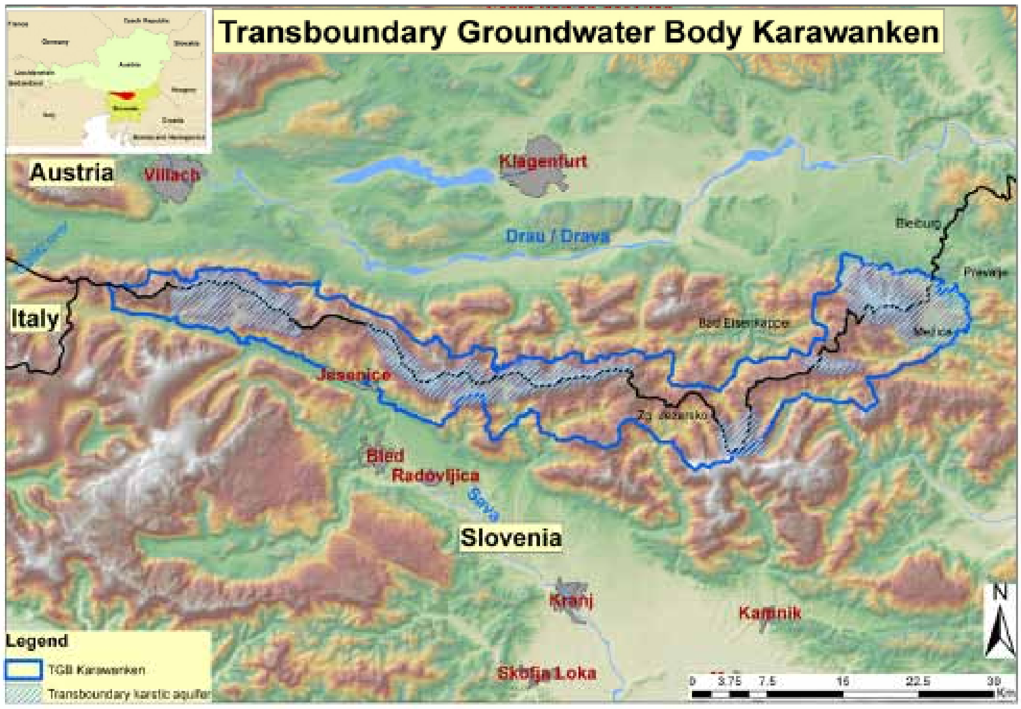
The national border between Austria and Slovenia in the Karawanke/Karavanke mountain range is also an orographic division: In the southern part of the Karavanke, surface water flows into the Sava River and partly also into the Drava River, and in the northern region, surface waters flow towards the north into the Drava River. About 3600 springs have been recorded on both sides of the Austrian-Slovenian border (Figure 26). Most of these springs have a small discharge. Some very large springs flowing from karst aquifers were found to have a recharge area extending across the border (Brencic & Poltnig 2008). With the opening of the borders and with the membership of Slovenia and Austria in the European Union, this area – previously strictly divided by the border – became unified and open to development.

The Karavanke/Karawanken transboundary groundwater was defined in 2004 based on the mutual agreement of the Drava/Drau Commission between the Republics of Austria and Slovenia.

The determination of an official transboundary region (according to the WFD) was based on the fruitful cooperation between Austria and Slovenia at the bilateral water management commission for the Drava/Drau River basin. The Drava/Drau Commission was founded shortly after World War II; at the beginning, it was dedicated solely to surface water management. After the construction of the Karavanke/Karawanken road tunnel in the 1990s, when large underground springs were created by the tunnel construction and large groundwater resources uncovered, a commission consisting of a bilateral expert body was founded to assume responsibility for drinking water reserves in the Karavanke/Karawanken mountain range. Since the 1990s, this expert body has met twice per year; in 2011, the Karawanke/Karavanke Commission will celebrate its 40th meeting. All bilateral groundwater transboundary flow issues related to investigation, management, and protection are discussed in this group.

Until 2006, the work of the commission was mainly dedicated to investigation of water resources. After 2006, the work of the expert body was dedicated more towards the protection of springs used for drinking water with transboundary recharge zones. Despite strong commitments by both parties to protect spring recharge zones and the implementation of all international legal regulations connected with transboundary water resources management, several practical and operational questions are still open. In both countries, good practices for the protection of drinking water exist that create the basis for expert identification of protection zones. Comparisons show a high level of similarity between the two countries regarding the identification of such zones. However, the legal realisation is different in Austria and in Slovenia (e.g., differences in the ownership of groundwater; please see (Table 5)). Currently, a mutual agreement on practices of groundwater protection has been reached. For the near future, information will be collected for all springs with transboundary recharge zones, which will form the foundations for their legal protection in accordance with the national laws of Austria and Slovenia.

FIGURE 26: Karavanke/Karawanken Pilot Site with its transboundary groundwater body.



CASE STUDY 2

The Scrivia River Contract: an Interregional Strategy to Improve Integrated Water Management and Planning

Within the framework of the Alp-Water-Scarce project, an interregional River Contract was signed between the province of Genova (through the Development Agency GAL Genovese) and the province of Alessandria for one of the project's Pilot Sites: the Scrivia River basin in Italy.

Based on regional legislation, the province of Alessandria has been managing river basins by using River Contracts as instruments for their negotiated governance. A River Contract permits the development of a holistic view of a river basin, taking into account not only the river ecosystem per se but also socio-economic factors. One of the main aims of a River Contract is to support the governance of the local development processes, involving all relevant bodies engaged in activities of river redevelopment as well as stakeholders from

concerned municipalities and private parties. Furthermore, the adoption and implementation of a River Contract enables consideration of criteria such as public utility, economic performance, social value, and environmental sustainability when seeking effective solutions for river basin redevelopment.
In a further step, the Contract is a means to apply a sectoral framework that becomes the ideal consultation forum for a harmonic application of different land use policies at the local scale.
Based on common activities within the Alp-Water-Scarce project, in September 2010 the two provinces of Alessandria and Genova signed a Memorandum of Understanding, which is the basis for the River Contract. To date, the common governance process has just begun, e.g., the members and representatives of the steering committee of the River Contract have been selected. This committee is a policy-making body in which local political representatives participate.
The main purpose of the Scrivia River Contract is torrent protection, in particular the water quality, as well as the following measures:

- Water protection and management
- Landscape/environmental recovery
- Enhancement of multifunctional farming activities
- Land protection
- Land enhancement
- Shared process management

Another of the aspects addressed either in the Memorandum signed in September 2010 or in the River Contract is the creation of a new "awareness and knowledge culture" regarding water use. Moreover, the importance of increasing the circulation of information on water management activities at the river basin scale is noted.

RECOMMENDATIONS

- National legislative hurdles for transboundary cooperation should be evaluated and reduced.
- Cooperative activities between countries and within river basins should be intensified.
- Official cooperation agreements for smaller catchments should be established.
- The implementation of transboundary water protection zones should be considered.
- Transboundary cooperation to perform shared studies on the development of water resources should be encouraged.
- Data exchange should be facilitated.
- Planning activities at the river basin scale should be promoted.

5.2.5 Results from the Stakeholder Survey of Alp-Water-Scarce

In the Alp-Water-Scarce project, stakeholders were asked to identify possible solutions for how to address water scarcity in the Alps.
Globally, it was observed that stakeholders did not indicate one ultimate solution per se but rather selected solutions from those proposed. In other words, it seems that the complex and often regionally specific problem of water scarcity demands a wide variety of complementary solutions.
However, a few more specific observations could be made: 34% of the interviewed stakeholders proposed water-saving options (13%: developing water economising measures;

11%: reduce water consumption; 10%: encourage re-use) or the improvement of infrastructure (20%) as solutions. “Better water management” was also seen as an important factor (12%).
These results stress the fact that there is still potential for water-saving measures that should be accompanied by increasing awareness-building, as well as for measures that address the inefficiencies of inadequate infrastructure.
Focusing on the country level, in Austria solutions to overcome water scarcity were connected to reductions in water consumption, encouraging water re-use, the adoption of measures to save water, and the protection of water resources. In Italy, improvements in infrastructure and increases in efficiency were highlighted. In Slovenia, stakeholders considered the cultivation of drought-resistant agricultural crops, the protection of water resources, and the improvement of water management to be most important. French stakeholders also prioritized water re-use (11%), as well as the implementation of water-saving measures (13%). When asked to identify best practices, it was observed that the practices proposed were related to overcoming communication problems and to raising awareness regarding water-saving measures. Others were related to the concerted management of water resources (e.g., river contracts) or technical solutions (e.g., creation of water retention pools on private land).

5.3 Towards a Decision-Support System to Address Water Scarcity: The Concept of an Early Warning System

The term “Early Warning System” (EWS) can be encompassed within the more general concept of a “Decision Support System” (DSS) for “Integrated Water Resources Management” (IWRM). The design of this type of EWS gives structure to the decision-making process. Stakeholder participation is essential for the system’s development, its evaluation, and continuous improvement.
The main objective of an EWS is to enable knowledge-based decision-making by combining data and models in order to characterise and control water system dynamics. An EWS should contribute to the issues described in the following paragraphs (Figure 27).

- **Retrospective analysis**
  The re-analysis of past events and trends using monitoring and modelling is essential in order to characterise the seasonal and inter-annual variability of the availability and demand for water resources. The estimation of flow statistics and the re-analysis of past water scarcity events contributes to the understanding of the system. It also constitutes a primary building block for short-term management and long-term planning.

- **Short-term management**
  The mitigation of water scarcity can be achieved by enforcing appropriate restriction measures and optimizing water allocation among competing uses. The comparison of the current status with reference statistics is relatively simple and usually informative. The establishment of short-term projections requires the estimation of future water availability and demand.

- **Long-term planning**
  In order to assess the vulnerability of a current development strategy (i.e., baseline scenario) but also to evaluate adaptation strategies for climate change (Adger et al. 2007), it is necessary to explore alternative scenarios for the evolution of natural and anthropogenic systems (e.g., evolution of climate forcing, alternative measures or policy options, structural or non-structural changes).

In order to address the objectives described above, the system should include the following consolidated and interactive components:

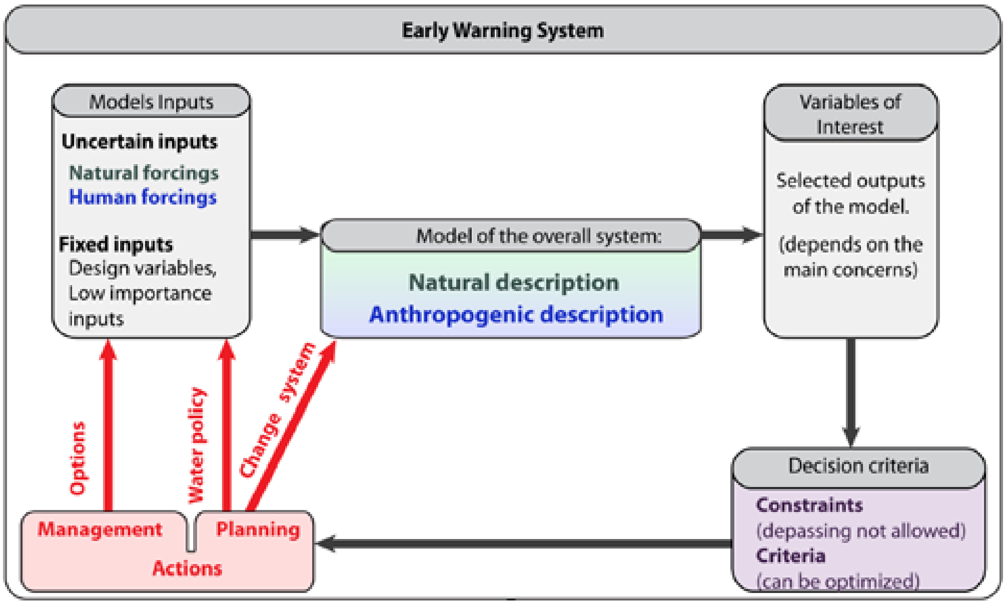
1. **Monitoring network**
   The acquisition, transmission, and storage of observation data related to hydro-meteorological variables (precipitation, discharge, aquifer water levels) and anthropogenic factors (drinking water usage, water used for agriculture and for snowmaking, etc.) are essential components of the EWS.
   Long-term monitoring and analysis of observational data enable improved system understanding and characterization. There is also a need for the calibration and corroboration of the integrated model and for the development of climatic and anthropogenic forcing scenarios.

2. **Integrated hydrological model**
   The hydrological cycle in mountain ecosystems is strongly influenced by anthropogenic factors; conversely, socio-economic activities rely on the availability of water resources. An integrated model should be a parsimonious but reliable representation of this complex coupled system. In order to describe and modulate water and energy transfers, the appropriate level of representation of reality depends on the available observational data (Schaefli & Huss 2010).
   In addition to the modelling of mountain hydrology, already a challenge (Klemens 1990), it is necessary to understand, quantify, and parameterize anthropogenic actions. Most anthropogenic effects (i.e., withdrawal, storage) can be represented as source and sink terms in the hydrologic model formulation. In order to ensure the interactivity of the EWS, the integrated model should enable the formalization of both management and planning actions.

3. **System analysis tools**
   Optimization methods are required for identification of the appropriate water allocation strategy given the available water, the required demand, and the constraints to be respected (e.g., optimal ecological flow). Moreover, mathematical and statistical tools are also needed to combine model and data using data assimilation (e.g., Nagler et al. 2008) and to understand and quantify uncertainty (Van der Sluijs 1996; Walker et al. 2005).
   Whereas the goal of uncertainty analysis is the quantification and propagation of various sources of uncertainty, the objective of sensitivity analysis is to estimate the relative contributions of all model inputs (Saltelli et al. 2000). Sensitivity analysis of the integrated system will also provide guidelines on where to allocate efforts and resources in order to improve the system's consistency, accuracy, robustness, and transferability.

4. **Anticipation and foresight concepts and methods**
   This system component is dedicated to the generation of future climatic and anthropogenic forcings. It plays an important role for both short-term management (anticipation/prognosis) and long-term planning (foresight/scenarios). In fact, anticipation under some circumstances (e.g., important time horizons for reactive hydrological cycle components) and foresight in all cases require the temporal extrapolation of model inputs (e.g., expected precipitation and water consumption). This "extrapolation", which usually relies on important assumptions, is also characterized by important uncertainties (Horton et al. 2006).
   Moreover, in order to define management options (short-term anticipation) and build alternative anthropogenic scenarios (long-term foresight), stakeholders should be involved (Mahmoud et al. 2009). In order to include structural and non-structural changes, the integrated model should be flexible, which is a necessary requirement for the development of a framework and recommendations for scenario building.

FIGURE 27:
An Early Warning System in a more general concept of a Decision Support System.



5.4 Summary and Conclusion

The work carried out within the "Alp-Water-Scarce" project has resulted in a set of recommendations based on the case studies described. Common to all these recommendations are the needs to preserve the water resources of the Alps for future generations, to meet increasing water demand, and to cope with climate change-induced stress on those resources. The strong commitment of public institutions to cooperate at regional, national, and transalpine levels and a common understanding of the terms "water scarcity" and "drought" are the preconditions for the implementation of long-term measures to address water scarcity.

The experience of Alp-Water-Scarce has shown that learning from each other by identifying and analysing challenges related to water resource problems on a transalpine level can be very fruitful.

Consequently, the discussion and work must continue in order to promote the concepts and to further elaborate the tools developed in Alp-Water-Scarce. One of the main conclusions is that an "Alpine Water Management Committee" consisting of water managers, researchers, and representatives from various sectors should be established.

The short version of these recommendations has been translated into German, French, Italian, and Slovenian to increase awareness on the topic and to guarantee a broad audience.

6 References

Abegg B, Agrawala S, Crick F, Montfalcon A (2007): Climate change impacts and adaptation in winter tourism. In: Agrawala S (ed.): Climate change in the European Alps: Adapting winter tourism and natural hazards management, pp. 25-58.

ACQWA - http://www.unige.ch/climate/Projects/ACQWA.html

Adger W, Agrawala S, Mirza M, Conde C, O'Brien K, Pulhin J, Pulwarty R, Smit B, Takahashi K, Parry M, Canziani O, Palutikof J, van der Linden P, Hanson C (2007): Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, UK: Cambridge University Press, , pp. 717-743.

Auer I, Böhm R, Jurkovic A, Lipa W, Orlik A, Potzmann R, Schöner W, Ungersböck M, Matulla C, Briffa K, Jones PD, Efthymiadis D, Brunetti M, Nanni T, Maugeri M, Mercalli L, Mestre O, Moisselin JM, Begert M, Müller-Westermeier G, Kveton V, Bochnicek O, Stastny P, Lapin M, Szalai S, Szentimrey T, Cegnar T, Dolinar M, Gajic-Capka M, Zaninovic K, Majstorovic Z, Nieplova E (2007): HISTALP – Historical instrumental climatological surface time series of the greater Alpine region 1760-2003. International Journal of Climatology 27: 17-46.

Authority for Electricity and Gas (2011): http://www.autorita.energia.it/allegati/relaz_ann/10/ra10_1_2.pdf

Autorità di Bacino (1998): Piano di bacino del Fiume Piave. Adopted in 2001, approved in 2007 DPCM 21.09.2007 in GU n.112 del 14 maggio 2008.

Barnett TB, Adam JC, Lettenmaier DP (2005): Potential impacts of a warming climate on water availability in snow-dominated regions. Nature, 438: 17.

Beniston M (1994): Mountain Environments in Changing Climates. London and New York: Routledge Publishing Co., pp. 492.

Beniston M (2003): Climatic Change in Mountain Regions: a Review of possible impacts. Climatic Change, 59: 5–31.

Benischke et al. (2002): Wasserversorgungsplan Steiermark – Ein Leitfaden für die öffentliche Waserversorgung. – Amt der Stmk. LR., FA 19a, Graz.

BMBF (2011): Anpassungsstrategien an den Klimawandel für Österreichs Wasserwirtschaft – Langfassung. Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft, Sektion Wasser, Austria.

Böhm R, Auer I, Schöner W, Ganekind M, Gruber C, Jurkovic A, Orlik A Ungersböck M (2009): Eine neue Webseite mit instrumentellen Qualitäts-Klimadaten für den Grossraum Alpen zurück bis 1760. Wiener Mitteilungen, 216: Hochwässer: Bemessung, Risikoanalyse und Vorhersage.

Brenčič M, Poltnig W (2008): Podzemne vode Karavank: skrito bogastvo/Grundwasser der Karawanken: versteckter Schatz. Ljubljana: Geološki zavod Slovenije; Graz: Joanneum Research Forschungsgesellschaft, pp. 143.

Bundesgesetz über den Schutz der Gewässer, Gewässerschutzgesetz, GSchG 1991.

Burlando P, Rosso R (2002): Effects of transient climate change on basin hydrology. 2. Impacts on runoff variability of the Arno River, central Italy. Hydrol. Process., 16: 1177-1199.

COM (2009): White Paper. Adapting to climate change: Towards a European framework for action. 147, Brussels, Belgium.

Conseil Général de la Savoie (2010): Observatoire savoyard de l'environnement Bilan 2009. 17: 32-33.

Dalla Valle F, Saccardo I (1996): Caratterizzazione idrologica del Fiume Piave. Rel. 1225 UIGI.

DG Environment (2008): Drought Management Plan Report - Including Agricultural, Drought Indicators and Climate Change Aspects. Water Scarcity and Droughts Expert Network. European Communities, Luxembourg, 2007.

DG Environment (2009): Common implementation strategy for the Water Framework Directive (2000/60/EC). Guidance document No.24 River Basin Management in a Changing Climate. DG Environment European Commission.

Diaz HF, Beniston M, Bradley RS (1997): Climatic Change at High Elevation Sites. Dordrecht and Boston: Kluwer Academic Publishers, pp. 298.

EC (2001): Directive 2001/77/EC of the European Parliament and of the Council of 27 September 2001 on the promotion of electricity produced from renewable energy sources in the internal electricity market. Official Journal of the European Communities.

EC (2007): Communication from the European Commission to the European Parliament and the Council: Addressing the challenge of water scarcity and droughts in the European Union, 414 final. Commission of the European Communities.

EC (2008): Follow up Report to the Communication on water scarcity and droughts in the European Union. Commission of the European Communities.

EC (2010): Second Follow-up Report to the Communication on water scarcity and droughts in the European Union COM (2007) 414 final. Commission of the European Communities.

EC (2011): Third Follow-up Report to the Communication on water scarcity and droughts in the European Union COM (2007) 414 final. Commission of the European Communities.

EEA (2009): Regional climate change and adaptation - The Alps facing the challenge of changing water resources. EEA Report 8/2009, Copenhagen, 2009.

Elssasser H, Bürki R (2005): Klimawandel und Gletschertourismus. Bedrohte Alpengletscher. Alpine Association, Alpine Raumordnung, 27: 16-27.

ENSEMBLES: http://www.ensembles-eu.org/

EurAqua (2004): Towards a European Drought Policy. Discussion document prepared by EurAqua network of Europe's leading freshwater research organisations.

European Drought Centre: http://www.geo.uio.no/edc/

European Parliament (2007): Directive 7007/60/EC - Flood directive.

Water Scarcity and Droughts EU policy:(http://ec.europa.eu/environment/water/quantity/scarcity_en.htm).

GlowaDanube: http://www.glowa-danube.de/de/home/home.php

GT "Savoie 2020" (2010): Groupe de travail Savoie 2020 (2010) - Le Livre Blanc du climat en Savoie.

Hänggi P, Plattner C (2009): Projekt Klimaänderung und Wasserkraftnutzung. Schlussbericht der Vorstudie. Geographisches Institut Universität Bern und Netzwerkwasser im Bergebiet, Davos.

Harum T, Poltnig W, Ruch C, Freundl G, Schlamberger J (2008): Variability and trends of groundwater recharge in the last 200 years in a South Alpine groundwater system as consequence of climate change. Geophysical Research Abstracts, 10. EGU General Assembly 2008, Vienna.

HISTALP: www.zamg.ac.at/histalp

Horton P, Schaefli B, Mezghani A, Hingray B, Musy A (2006): Assessment of climate-change impacts on alpine discharge regimes with climate model uncertainty. Hydrological Processes 20/10: 2091-2109.

Iimi A (2007): Estimating global climate change impacts on hydropower projects: Applications in India, Sri Lanka, and Vietnam. Policy research working paper 4344. The World Bank.

Kaiser C, Mach T (2004): Wasser für die Landwirtschaft - Bestandsaufnahme und Bedarfsermittlung. Amt der Stmk. Landesreg., FA 19A, Graz.

Klemes V (1990): The modelling of mountain hydrology: the ultimate challenge. Hydrology of Mountainous Areas. Proceedings of the Strbské Pleso Workshop, Czechoslovakia, June 1988. IAHS, 190.

KLIWA: http://www.kliwa.de/

Law on the "Protection against Natural and Other Disasters Act - Zakon o varstvu pred naravnimi in drugimi nesrečami« (Official Gazette of RS 64/1994 and latter amendments – last from 2010).

LEMA (2006): Loi n°2006-1772 du 30 Décembre 2006 sur l'Eau et les Milieux Aquatiques".

Mahmoud M, Liu Y, Hartmann H, Stewart S, Wagener T, Semmens D, Stewart R, Gupta H, Dominguez D, Dominguez F, Hulse D, Letcher R, Rashleigh B, Smith C, Street R, Ticehurst J, Twery M, Van Delden H, Waldick R, White D, Winter L (2009): A formal framework for scenario development in support of environmental decision-making. Environmental Modelling & Software 24/7: 798-808.

Mauser W, Marke T, Stoeber S (2008): Climate Change and Water Resources: Scenarios of Low-flow Conditions in the Upper Danube River Basin. Earth and Environmental Science, 4: 1-11.

Ministère de l'Ecologie et du Développement Durable / French Ministry of Environment and Sustainable Development (2005) - Guide methodologique, mesures exceptionnelles de limitation ou de suspension des usages de l'eau en période de sécheresse / Methodological guide, exceptional measures for the limitation and suspension of water usage during drought periods, Direction de l'eau / Water Direction, 30 pages [access 05/2011 http://www.developpement-durable.gouv.fr/IMG/pdf/DGALN_Guide_mesures_restrictions.pdf]

MontanAqua: http://www.montanaqua.ch/

Moser D, Sauberer N, Willner W (2011): Generalisation of drought effects on ecosystem goods and services over the Alps. Alp-Water-Scarce Internal Project Report.

Müller H, Weber F (2008): 2030, Der Schweizer Tourismus im Klimawandel. Forschungsinstitut für Freizeit und Tourismus, Bern.

Nagler T, Rott H, Malcher P, Müller F (2008): Assimilation of meteorological and remote sensing data for snowmelt runoff forecasting. Remote Sensing of Environment 112/4: 1408-1420.

National Drought Mitigation Center of the University of Nebraska-Lincoln, US: http://drought.unl.edu/whatis/concept.htm

New York Times (1921a): Drought breaking up glaciers in the Alps. The New York Times, 17 March, 1921.

New York Times (1921b): Burning drought in Alps. The New York Times, 5 August, 1921.
OcCC (2007): Klimaänderung und die Schweiz 2050. Erwartete Auswirkungen auf Umwelt, Gesellschaft und Wirtschaft. Beratendes Organ für Fragen der Klimaänderung OcCC. Bern, Schweiz.
OECD (2007): Climate change in the European Alps. Adapting winter tourism and natural hazards management. Paris, France.
ÖVGW (2008): Österreichische Vereinigung für das Gas- und Wasserfach: Richtlinie W88 Anleitung zur Einführung eines einfachen Wasser-Sicherheitsplanes 5/2008, Vienna.
Paccard P (2010): Gestion durable de l'eau en montagne: le cas de la production de neige en stations de sports d'hiver. Thèse de doctorat de géographie, Université de Savoie.
PNLCC (2000): Programme National de Lutte contre le Changement Climatique, France.
Prettenthaler F, Gobiet A, Habsburg-Lothringen C, Steinacker R, Töglhofer C, Türk A (2007): Auswirkungen des Klimawandels auf Heiz- und Kühlenergiebedarf in Österreich. Endbericht StartClim 2006. Universität Graz, Wegener Zentrum, Austria.
PSAC (2009): Water and water management issues - Report on the state of the Alps. Permanent Secretariat of the Alpine Convention, Bolzano, 2009.
RECLIP: http://foresight.ait.ac.at/SE/projects/reclip/
Reiter A, Strasser U, Mauser W (2008): Effects of snow cannons and artificial snow on energy industry and hydrology in the province Salzburg (Austria). Geophysical Research Abstracts, Abstracts of the European Geosciences Union General Assembly 2008, Vienna.
Resolution on the National Programme of Protection against Natural and other Disasters 2009-2015 Resolucija o nacionalnem programu varstva pred naravnimi in drugimi nesrečami v letih 2009 do 2015" (Official Gazette of RS – 57/2009).
Schaefli B, Hingra B, Musy A (2007): Climate change and hydropower production in the Swiss Alps: Quantification of potential impacts and related modeling uncertainties. Hydrology and Earth System Sciences 11(3): 1191-1205.
Schaefli B, Huss M (2010): Simulation of high mountainous discharge: how much information do we need? Hydrology and Earth System Sciences Discussions 7(5): 8661--8702.
Saltelli A, Chan K, Scott E, Saltelli A, Chan K, Scott E (2000): Sensitivity analysis. Wiley.
Saulnier GM, Castaings W, Reszler C, Hohenwallner D, Brancelj A, Bertoncelj I, Brencic M, Brun A, Cadoux-Rivollet M, Cainelli O, Calvi C, De Bona A, Doering M, Defrancesco C, Dutto E, Freundl G, Harum T, Jamsek A, Klemencic-Kosi S, Kopeinig C, Klug H, Lachenal P, Lascours S, Leskosek T, Mezek T, Mignone N, Mori N, Mourembles C, Neuwirth J, Paccard P, Pascariello A, Pergher P, Poltnig W, Pusenjak M, Rampazzo R, Rikanovic R, Robinson C, Rollando A, Schlamberger J, Scussel R, Siligardi M, Suette G, Valentar V, Vecellio C, Wagner K, Zadravec D, Zalavari P, Zessar H (2011): Climatic scenarios guideline, Alp-Water-Scarce (Interreg IV B, Alpine Space Programme, project 5-1-3-F), pp 1-13.
Schippek-Erhart W (2002): Wasserbedarfsprognose. In: Benischke et al. (eds.): Wasserversorgungsplan Steiermark - Ein Leitfaden für die öffentliche Wasserversorgung. Amt der Stmk. Landesreg., FA 19A.
Schöner W. (2009): Paläoklimainformation aus Kenngrössen der Gletschermassenbilanz - Beispiele für die Alpen seit der ausgehenden kleinen Eiszeit. Alpine Space – Man and Environment, 6.
Steiger R, Mayer M (2008): Snowmaking and climate change: Future options for snow production in Tyrolean ski resorts. Mountain Research and Development 28, 3-4: 292-298.
Strasser U, Bernhardt M, Weber M, Liston GE, Mauser W (2008): Is snow sublimation important in the alpine water balance? The Cryosphere, 2: 53-66.
Sušnik A (2005): IRRFIB model and its practical usage for drought estimation in Slovenia. In: Maracchi G, Kajfez-Bogataj L, Orlandini S, Rossi F, Barazutti M (eds.): Irrigation and pest and disease models: Evaluation in different environments and web-based applications. European Commission, Brussels, 36-42.
Swiss Federal Office of Energy (2011): http://www.bfe.admin.ch/themen/00490/00491/index.html?lang=en
Turc L (1954): Calcul du bilan de l'eau évaluation en fonction des précipitations et des températures. Int. Assoc. Sci. Hydrol., 38/3: 188–202.
UNDP: http://europeandcis.undp.org/environment/wg/show/FA499AD7-F203-1EE9-BF1DD1F9F83C486F
Van der Sluijs J (1996): Integrated Assessment Models and the Management of Uncertainties, Technical report, IIASA working paper 96-119, Laxenburg, Austria.
Viviroli D, Weingartner R, Messerli B (2003): Assesssing the Hydrological Significance of the World's Mountains. Mountain Research and Development, 23: 32–40.
Viviroli D, Dürr HH, Messerli B, Meybeck M, Weingartner R (2007): Mountains of the world – water towers for humanity: typology, mapping and global significance. Water Resources Research, 43(7).
Viviroli D, Archer DR, Buytaert W, Fowler HJ, Greenwood GB, Hamlet AF, Huang Y, Koboltschnig G, Litaor MI, López-Moreno JI,

Lorentz S, Schädler B, Schwaiger K, Vuille M, Woods R (2010): Climate change and mountain water resources: overview and recommendations for research, management and politics. Hydrol. Earth Syst. Sci. Discuss., 7: 2829–2895.

Walker W, Harremoes P, Rotmans J, Van der Sluijs J, Van Asselt M, Janssen P, Von Krauss MK (2005): Defining Uncertainty: A Conceptual Basis for Uncertainty Management in Model-Based Decision Support. Integrated Assessment 4/1.

Wasserrechtsgesetz (1959): BGBl. Nr. 215/1959 zuletzt geändert BGBl. I Nr. 123/2006.

Wasserversorgungsplan Steiermark: http://www.wasserwirtschaft.steiermark.at/cms/beitrag/10188852/4660005

WHO – Water Safety Plans: http://www.who.int/water_sanitation_health/dwq/WSP/en/index.html;

WFD (2000): Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for the Community action in the field of water policy. European Parliament 2000.

Zierl B, Bugmann H (2005): Global change impacts on hydrological processes in Alpine catchments. Wat. Res. Res., 41: 1-13.

UNISDR (2005): Hyogo Framework for Action 2005-2015: Building the resilience of nations and communities to disasters.

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7 Annex

AUSTRIA

Instruments of water governance and water management
In Austria, the legislative authority for water governance is constituted at the federal level. The most important source of law is the Wasserrechtsgesetz 1959 (Wasserrechtsgesetz 1959), which in the current version also includes the Water Framework Directive of the EU. The legal text of the Wasserrechtsgesetz can be downloaded at:

http://www.jusline.at/Wasserrechtsgesetz_%28WRG%29_Langversion.html

Other sources of law are:
Wasserbautenförderungsgesetz 1985, Wildbach- und Lawinenverbauungsgesetz (RGBL Nr. 117/1884), Altlastensanierungsgesetz (1989), Gewässerzustandsüberwachungsverordnung (BGBl.II Nr.479/2006), Qualitätszielverordnung Chemie Grundwasser (BGBl. II Nr. 461/2010), the Groundwater Threshold Value Ordinance (BGBl. Nr.502/1991, i.d.F. BGBl.II Nr.147/2002), and the Wasserkreislauferhebungsverordnung (WKEV BGBl.II Nr.478/2006).

In addition, the Building Act (Baurecht), Trade Law (Gewerbeordnung), Mineral Resources Act (Mineralrohstoffgesetz), Forestry Law (Forstgesetz), and Food Law (Lebensmittelgesetz) may also be relevant for water management issues.
Water usage rights are registered in the Wasserbuch (Waterbook), which is accessible online via the websites of the provinces (Länder).

In Austria, water bodies are either public or private property. Public water bodies are mentioned in Annex A of the Wasserrechtsgesetz (Wasserrechtsgesetz 1959), whereas private water bodies belong to the land owner (this is true for groundwater, springs, and water in wells and ponds on private land).

The following authorities (Wasserrechtsbehörden) are involved in water management issues:
1. Federal Ministry of Agriculture, Forestry, Environment and Water Management (National level)
2. Head of the province (NUTS 2 level)
3. District administration (NUTS 3 level)

Unless otherwise specified, the district administration (NUTS 3 level) is the responsible water management authority at the first level of jurisdiction.
The water management authorities decide whether a water body is public or private, for example.

1. **Water governance at the national level**
   At the national level, the ministerial body responsible for the implementation of the Wasserrechtsgesetz is the "Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management".
   The responsibilities of this ministry include:
   1. technical coordination of the activities of the water managing authorities in the provinces
   2. handling water management issues relevant to more than one province
   3. compilation of institutional conventions for a common water management planning policy.

2. **Water governance at the NUTS 2 level (Bundesländer)**
   The territory of Austria is divided into 9 provinces: Burgenland (Burgenland), Kärnten (Carinthia), Niederösterreich (Lower Austria), Oberösterreich (Upper Austria), Salzburg (Salzburg), Steiermark (Styria), Tirol (Tyrol), Vorarlberg (Vorarlberg), and Wien (Vienna).

The head of the province (Landeshauptmann, Landeshauptfrau) represents the planning authority for water management issues and is responsible for (amongst other aspects):

a) consideration of all questions that concern water management planning in the province
b) monitoring the development of water management
c) collection of data relevant to water management planning
d) implementation of anticipatory water management planning actions
e) creation of basic information to establish protected areas, rehabilitation programmes, etc.
f) recognition of economic interests regarding water management vis-à-vis the planning agency
g) recognition of the necessity to protect the drinking water supply and the supply of process water in the province.

The head of the province must make available to the public in each district a Wasserbuch (waterbook), in which all water-related rights are listed. If such a water right extends beyond a single province, the Federal Ministry of Agriculture, Forestry, Environment and Water Management decides which head of the province has the right to include it in the respective waterbook.

The waterbook includes details of water rights, official documents dealing with water rights, and an overview of water cooperatives and water associations, water management planning, and the location of areas from which water is extracted.

3. Water governance at a NUTS 3 level (Bezirk)

Unless otherwise specified, the district administration is the responsible authority at the first level of jurisdiction.

At this level, so-called Wassergenossenschaften (water cooperatives) or Wasserverbände (water associations) can be established.

Wassergenossenschaften (water cooperatives) are responsible for (amongst other aspects):

– provision of drinking water, supply water, and fire-fighting water
– drainage and irrigation as well as the functioning of the groundwater balance

If several communities are affected by planned measures, water associations can be established. A water cooperative can also be a member of a water association.

Legislation on drought and water scarcity

In the Wasserrechtsgesetz (Wasserrechtsgesetz 1959), the topic of water scarcity is not explicitly mentioned. Nevertheless, in the following articles water scarcity and drought issues are touched upon:

§ 25 Einschränkung bestehender Wasserbenutzungsrechte bei Wassermangel - A reduction of existing privileges of water usage in case of water scarcity
§ 30 Ziele - Aims:the sustainable protection of water resources to handle droughts, etc.
§ 34 Schutz von Wasserversorgungsanlagen (Wasserschutzgebiete) - Water protection areas
§ 35 Sicherung der künftigen Wasserversorgung - Protection of future water supply
§ 55f Maßnahmenprogramme - Measures to be taken in case of drought events
§ 66 Schutz des landwirtschaftlichen Wasserbedarfs - Protection of water demand for agriculture to avoid drought

Adaptation measures for the effects of climate change

In 2011, the Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management published a study on "Adaptation Strategies for Austrian Water Management for the effects of climate change" (BMBF 2011). This report concluded that for the southern part of Austria, where a decrease in precipitation is expected, as well as for the eastern part which traditionally experiences less rain, a reduction in groundwater recharge can be expected in the future. This will be the inverse for in northern and western Austria, where an increase in precipitation can be expected.

Furthermore, the report gives an outline of water availability in Austria in the future: due to the high availability of water and thus the expected small changes in groundwater recharge, water scarcity is NOT anticipated for larger areas. However, locally, occurrences of periods of water scarcity can be expected to increase in regions with adverse water conditions. The authors of the report also propose the establishment of early warning systems.

FRANCE

Instruments of water governance and water management

In France, the most important source of law concerning water management is the Law on Water and Aquatic Evironments or LEMA (Loi n°2006-1772 du 30 Décembre 2006 sur l'Eau et les Milieux Aquatiques) of 2006 (LEMA 2006). This text is a general law covering water management issues and includes the provisions of the Water Framework Directive.

Bodies of water in France are either state-owned (cours d'eau domanial) or non-state-owned (cours d'eau non-domanial).

- State-owned water bodies are those registered as part of the public waterways domain (Domaine Public Fluvial).
- The non-state-owned water bodies are defined negatively as all water bodies not registered as state-owned. They are generally smaller and belong to riverside residents. Each riverside property owner has property rights over the riverbed up to its centre for the corresponding length of riverside owned; the owner is obliged to ensure its maintenance and the preservation of its ecological state.

In general, the water management policy of France is based on 7 core principles:

- an integrated approach;
- territorial management organised within the boundaries of each river basin;
- strong stakeholder involvement for participatory management;
- economic incentive tools: polluter-pays and user-pays principles;
- scientific and technical expertise coordinated by the French National Agency for Water and Aquatic Environments;
- long-term planning; and
- public authority responsibility for drinking water supply and wastewater treatment. These services can either be provided by the local public authority itself or contracted to a private company.

At the national, river basin, and sub-watershed level, water management policy is defined based on the decisions of committees consisting of representatives from the State (administration), local government, and users (stakeholders).

After the 2003 drought, drought management measures were added to the general water management policy of France. These measures define specific proceedings in the case of drought.

1. **Water governance at the national level**

   At the national level, the Ministry of Ecology, Sustainable Development, Transportation and Housing is responsible for water management. The Department for Spatial Planning, Housing and Nature defines and organises policy concerning water bodies in co-operation with other relevant Ministries (agriculture, health, industry, etc.) and ensures the supervision of water policies via its local representatives.

   In France, water is managed at the level of 6 main river basins by "river basin decision-making bodies". For each river basin, these groups bring together water agencies and river basin committees.

   The aims of the water agencies are to establish, calculate, and collect charges according to the polluter-pays principle; to initiate and provide financial and technical support for works to improve the condition of water ecosystems and reduce pollution; to assist the river basin committees in the development of river basin management plans (RBMP); to provide data on water quality; and to implement an integrated water resources management policy.

   The river basin committees are consultation and dialogue bodies that bring together stakeholders from different areas, such as local government, national institutions, end users, and experts. These committees create the River Basin Management Plans, define water management and water ecosystems protection policies, orientate the policy actions of the water agencies, and are consulted for all major infrastructure development.

The work of these two bodies is coordinated by the Préfet coordinateur de basin for the region (NUTS 2 level).

2. **Water governance at the NUTS 2 level**
   At the regional level in France, water is managed by state agencies. The agency mainly involved is the DREAL (Regional Environment, Spatial Planning and Housing Agency), which coordinates water supervision services and the establishment of the RBMPs; carries out environmental evaluations and ensures the provision of information to the general public; monitors water quality, especially that of ecosystems; monitors hydrology, hydrometry, and rainfall levels; controls facilities registered as dangerous for the environment; and monitors and prevents risks.
   The ARS (Regional Agency for Health) is also involved in monitoring the quality of drinking water, leisure waters, and health risks.

3. **Water governance at the NUTS 3 level**
   A representative of the state coordinates water policy at the NUTS 3 level. The role of this representative is to grant permission for classified facilities, to ensure water supervision, and to organise public consultation before publishing local decrees to limit water usage in the case of drought.
   Various NUTS 3 level agencies ensure water management and water supervision at this level: DDT (Direction Départementale des Territoires = Departmental Land Agency), ONEMA (Office National de l'Eau et des Milieux Aquatiques = National office for Water and Aquatic Environments), and Local units of the ARS.

4. **Water governance at the LAU level**
   The mayor (in communes) or the president (in districts) is responsible for drinking water supply, drinking water quality, and waste water treatment. He or she must inform users about the quality of water distributed and present an annual report on the quality and price of water supplied and waste water treatment. Furthermore, this leader is also responsible for risk management and for preparing emergency action plans to be enforced in the commune in the case of a crisis situation.

Legislation on drought and water scarcity

Water scarcity management is addressed by several laws. The most important, the Law on Water and Aquatic Environments of 30 December 2006 (LEMA 2006) deals, amongst other aspects, with the "conservation of water resources and aquatic environments" and "quantitative management" where water quantity and adaptation to climate change are at issue.
The most important principles are 1) adaptation to climate change; 2) priority is always given to drinking water supply; 3) quotas for sharing water and a unique authorised representative for all water users who make withdrawals; 4) limited use of water by factories that present a risk to the environment in the case of an exceptional event.
Other national legislation that addresses water management includes: The Environment Code (Code de l'Environnement), the Urban Development Code (Code de l'Urbanisme), the Rural Code (Code Rural), the General Local Government Code (Code Général des Collectivités Territoriales), and the Law of National Involvement for the Environment (Loi du 12 juillet 2010 portant engagement national pour l'environnement [Grenelle 2]).

Early Warning Systems

Following the dry summer of 2003 and its consequences, in 2004 a national committee was set up to monitor the effects of droughts on water resources. The committee acts as a forum for the exchange of information on hydrological conditions in periods of possible or actual rainfall deficit and the impacts on different water uses and on water ecosystems. It also coordinates national communication activities.
Local authorities inform the committee about measures taken at a local level. In periods of drought, public bodies at the local level can issue by-laws to limit water withdrawals in their territories. They organise meetings with all relevant water users and stakeholders and decide whether to set a by-law or not and which level of restriction should be applied.

At the national level, in 2005 the French Ministry of Ecology and Sustainable Development issued a "Methodological guide of exceptional measures for the limitation and suspension of water usage during drought periods" (Ministère de l'Ecologie et du Développement Durable 2005). This document states that by-laws issued by local public bodies during periods of drought must be established step-by-step, be adapted to the severity of the situation, and can only be enforced for a limited period of time. Two core principles must be respected: equality between users from different areas and upstream-downstream solidarity. The hydrological situation must be monitored; based on its evolution, further restrictions can be enforced.
By-laws are intended to allow quick implementation of efficient step-by-step measures based on the monitoring of piezometric and discharge levels. These measures will depend on the alert threshold set by the local authority.

Adaptation measures for the effects of climate change
The "National Programme of Measures against Climate Change" (PNLCC 2000) was drafted in 2000 based on two pillars: mitigation and adaptation.
In 2009, the French Minister of Ecology, Sustainable Development, Transportation and Housing announced an adaptation strategy to deal with climate change. A "National Adaptation Plan" is expected to be adopted at the end of 2011. It will be accompanied at the local level by climate-energy plans for every commune and local government.

ITALY

Instruments of water governance and water management
In Italy, the most important source of law concerning the management of water resources is Legislative Decree No. 152 of 3 April 2006 (Regulation on environmental matters). It implements the provisions of the EU Water Framework Directive (2000/60/CE).

All surface and groundwater, even if not extracted from the subsurface, are the property of the State or of the autonomous provinces of Trento and Bolzano.
Furthermore, the following goods are also property of the State: sea shores, beaches, harbours, and aqueducts on public property.
The use of thermal, mineral, and geothermal springs is regulated by specific laws, in accordance with the division of competencies laid out in the Constitution.

Legislative Decree No. 152/2006 defines the eight main Italian river districts; water management is organised at the level of each of these river districts by a River Basin Authority.

1. **Water governance at national level (Arts. 57 – 58, competencies)**
   The State has competence in the following areas:
   - activities of water management planning and programming,
   - River Basin Plans, and
   - national programmes of intervention.

   However, the regions and the autonomous provinces of Trento and Bolzano retain their competences in this area.
   The Committee of Ministers is responsible for overall vigilance and adopts acts of orientation and coordination of activities.
   The Minister for the Environment and the Protection of the Territory and the Sea takes the following actions:
   - puts forward proposals for the implementation of the water police service;
   - acts for the coordination of soil management policies, protection and use of water, and protection of the environment; and
   - coordinates the activities of the ministerial representatives in the River Basin Authorities.

   Additionally, the State-Regions Conference formulates opinions on a variety of issues, including the River Basin Plans.

A River Basin Authority has been set up for each of the eight main river districts identified in Italy. This public body is composed of:

- the Permanent Institutional Conference,
- the Secretary General,
- the technical-operational Secretariat, and
- the operational services of the Conference.

The Permanent Institutional Conference is the decision-making body. It is in charge of the orientation, coordination, and planning activities of the River Basin Authorities.

The tasks of the River Basin Authorities are:
to draw up the district River Basin Plan;
to elaborate the water management plan as part of the River Basin Plan;
to ensure consistency between the River Basin Plan and European, national, regional, and local rules, as part of the River Basin Plan, to carry out three different analyses: on the general characteristics of the river district, on the impact of human activities on the status of the surface and ground waters, and on the economic impact of water uses.

According to Art. 65 of Legislative Decree No. 152/2006, the River Basin Plan is a cognitive, normative, and technical-operational instrument. It is an instrument for planning and programming actions in light of the physical and environmental characteristics of the reference territory.
All of the measures adopted in the River Basin Plans are binding and must be enforced by all public administrations and private bodies. The territorial and regional plans and programs must be adapted to the rules of the River Basin Plan.

2. **Water governance at the NUTS 2 level (regional)**

The Italian Regions are required to draw up a water protection plan for their territories, consisting of a plan covering the statuses of water bodies and the quantitative and qualitative management of water. The Regions are also required, amongst other things:

- to participate in the Permanent Institutional Conference of the River Basin Authorities and consequently in drawing up River Basin Plans and
- to implement the activities set out in the River Basin Plan.

The autonomous provinces of Trento and Bolzano have wide-ranging competences related to state water property and water planning. In particular, the General Plan for the Use of Public Water (P.G.U.A.P.), approved in accordance with the State, takes the form of a planning instrument that allows coordination with the other regions and with the State on overall water management with respect to qualitative and quantitative aspects and safety aspects.

3. **Water governance at the LAU level (local)**

Local communities take part in the implementation of water management plans under the framework drawn up by each region or autonomous province and in compliance with the general rules on the competences of local bodies. The competencies of local communities are therefore defined by national and regional rules and can vary from one regional body to another.

Legislation on drought and water scarcity

In Italy, the qualitative and quantitative monitoring of surface water and groundwater is the responsibility of the regions and the autonomous provinces, in accordance with European and national rules (such as Legislative Decree No. 152/2006) and in compliance with national implementing regulations on standardization of data. As a result, monitoring of water quantity and rules on water use might vary from one region to another.
Art. 65 (3.D.1) of Legislative Decree No. 152/2006 stipulates that the measures to be taken in the event of the threat of drought are to be set out in the River Basin Plans.
Art. 93 (2) of Legislative Decree No. 152/2006, states that the regions, the autonomous provinces and the River Basin Authorities are responsible for identifying areas subject to or threatened by drought. Furthermore, Art. 167 states that in the event of drought, the use of water for agricultural activities takes precedence over other uses, with the exception of drinking water.

SLOVENIA

Instruments of water governance and water management
In Slovenia, the laws concerning water are set out in the Water Act of July 2002 (No. 001-22-101/02,
http://www.mop.gov.si/fileadmin/mop.gov.si/pageuploads/zakonodaja/okolje/en/vode.pdf). This text replaces the previous water law (dating from 1987) and foresees the implementation of the requirements of the European Water Framework Directive.

According to this document, water management in Slovenia is based on six core principles:
1. the principle of comprehensiveness, taking into account the natural processes and dynamics of water, and the links between and co-dependence of aquatic and semi-aquatic ecosystems in a water system;
2. the principle of long-term preservation of quality and the proper use of available water sources;
3. the principle of ensuring protection against adverse effects on waters arising from the need to ensure the safety of the population and property, taking into account the functioning of natural processes;
4. the principle of economic valuation of water, which includes the costs of imposing burdens on water and the costs of protecting and regulating waters;
5. the principle of public participation, which allows the public to participate in the adoption of water management plans;
6. the principle of surveillance of the best techniques available and of new scientific findings on natural laws.

Other national laws that refer to water include the Environment Protection Act (2004), the Protection against Natural and Other Disasters Act (1994), the Act Regulating the Sanitary Suitability of Foodstuff, Products and Materials Coming into Contact with Foodstuffs (2000), the Nature Conservation Act (1999), and some acts related to agriculture and forestry. The Water Act and other Acts are further completed by numerous laws and ordinances, such as those protecting drinking water resources.
At present, the Slovenian Government is working on the establishment and implementation of the River Basin Management Plans.
In Slovenia, the management of water, wetlands, and waterside land lies in the hands of the State. No organisations or authorities with regulatory status exist at regional or other levels.

1. Water governance at the national level
The national objectives of the water management policy of Slovenia are laid out in the National Water Management Programme, which was adopted at the proposal of the government by the National Assembly of the Republic of Slovenia for a maximum period of 12 years. Its implementation is assured via two water management plans which cover the two main river basins defined in the Water Act: the “Danube water system” and the “Adriatic water system” (Article 52, Territorial basis).
At the national level, the responsible institution is the Ministry of the Environment and Spatial Planning. Directly linked to the Ministry, the water director is responsible for legal and general questions regarding water.
One of the divisions of the Ministry is the “Environment Directorate”, which includes the Water Department. This department is responsible for the legal aspects of implementation.
The “Institute for Water of the Republic of Slovenia”, a semi-governmental agency that acts as the Water Institute according to article 160 of the Water Act, is responsible for the implementation of specific expert and development tasks for the Ministry of the Environment and Spatial Planning.
The Water Institute carries out the following expert tasks:
1. formulation of water management plans;
2. granting water rights and issuing water approvals;
3. determination of the boundaries of water and waterside land;
4. determination of areas of wetlands; and
5. activities in accordance with the founding act.

The “Ministry of the Environment and Spatial Planning” (MOP) and the “Agency for the Environment” (ARSO) are responsible for the implementation of the Water Act and all other water management issues. The “Office for Water Management” is part of the ARSO, comprising several sectors responsible for the authorisation process for water use and for water management at the sub-basin level. The headquarters of some sectors are located in regional centres and are focused on the larger rivers (e.g., Sector for River Sava watershed – Department for Upper River Sava in Kranj, which is responsible for Karavanke and part of the Julian Alps, among other areas). Within the headquarters, “river inspectors” are responsible for monitoring the status of the river and rehabilitation and improvement work.

Control

Under the auspices of the MOP, the “Inspectorate for the Environment and Spatial Planning” is the competent agency for control as established in the Water Act.

In the past, there were Water Management Companies responsible for the management of larger river basins. In the 1990s, many of these companies were privatised and some of them later collapsed or were bought by other companies. Today some of them hold contracts for the rehabilitation and maintenance of the river network. Larger-scale river rehabilitation and improvement works fall within the tendering process under the Public Procurement Act.

The Government has responsibility for the protection of drinking water resources, which is usually ensured by public waterworks companies. These companies are responsible for the waterworks and the control of groundwater recharge areas. In the event of problems, the environmental inspectorate must be informed.

Legislation on drought and water scarcity

In Slovenia, the relevant legislation relating to natural disasters is the “Protection against Natural and Other Disasters Act - Zakon o varstvu pred naravnimi in drugimi nesrečami” (Official Gazette of RS 64/1994 and latter amendments – most recently from 2010). The latest officially consolidated text of this law was published in 2006 (Official Gazette of RS 51/2006); it defines the organisational structure of responsibilities and procedures for the state and civil society with regard to disasters. Article 8 (like other articles) mentions natural disasters such as earthquakes, floods, landslides, and avalanches, but drought is also recognised. No exact definitions of the various natural disasters are given in this legislative document; they are understood per se.

Furthermore, article 41 of the act requires the preparation of a national programme for the protection against natural and other disasters for a period of five years. This programme is prepared by the Ministry of Defence and its “Administration of the Republic of Slovenia for Civil Protection and Disaster Relief” and is enacted by Parliament (current version: Official Gazette of RS 57/2009). The national programme also requires the preparation of a “National Plan for the Implementation of the National Programme for the Protection against Natural and other Disasters”.

The main part of the strategy against drought involves an inter-ministerial working body. This body is established to direct and coordinate the work and requirements related to the action plan with regard to international activities of “Building the resilience of nations and communities to disasters” under the Hyogo Framework for Action 2005-2015 (UN/ISDR 2005). Concomitantly, activities based on the Alpine Convention will be implemented.

In 2008, an “Adaptation strategy for Slovenian agriculture and forestry against climate change” was implemented by the government. The objective of this strategy is that the agriculture and forestry sectors participate in the securing of the drinking water supply and the improvement of flood control and responses to other disasters (e.g., wildfires, wind and snow damage, disease). In coordination with the strategies and programmes of other ministries (with the exception of the Ministry of Defence), mitigation measures against the consequences of drought (for example, related losses in agriculture and other economic sectors such as water supply; risk analysis for energy production, tourism, and other areas) are implemented. The “Drought Management Centre for Southeast Europe - Center za upravljanje s sušo v jugovzhodni Evropi” and other new institutions dealing with climate change will be incorporated.

A climate change-related integrated information system for monitoring the influences of climate change on agriculture and forestry has been launched with the aim of avoiding drought. For drought prevention and other extreme weather conditions that require societal responses and countermeasures, the implementation of an early warning system is planned.

The phenomenon of drought is hardly mentioned in other national Acts. In the Water Act, which represents the umbrella for water management in Slovenia, drought and water scarcity are only mentioned in Article 176:
"(1) Pursuant to the law, the competent inspector may issue a verbal decision and order the immediate execution of this decision;
(3) If drought emerges or if a water shortage or difficulties in the supply of drinking water might emerge for other reasons…"

SWITZERLAND

Instruments of water governance and water management
In Switzerland, the legislative authority is constituted at the federal level. The most important source of law is the Federal Law on the Protection of Waters WPL (Bundesgesetz über den Schutz der Gewässer, Gewässerschutzgesetz, GSchG 1991) from January 1991.
The legal text of the Law on the Protection of Waters (WPL) can be downloaded in German and French at
http://www.admin.ch/ch/d/sr/c814_20.html (German) or http://www.admin.ch/ch/f/rs/c814_20.html (French)

Other sources of law relevant to water management issues include: Federal Constitution of the Swiss Confederation, Article 76 water (Bundesverfassung der Schweizerischen Eidgenossenschaft - Art. 76 Wasser); Federal Law on Water Engineering (Bundesgesetz über den Wasserbau); Legal Ordinance on Water Engineering (Wasserbauverordnung (WBV); Law on Water Rights (Wasserrechtsgesetz (WRG); Legal Ordinance on Water Rights (Wasserrechtsverordnung (WRV); and Legal Ordinance on Water Protection (Gewässerschutzverordnung (GSchV) WPO).

Further relevant information is available in German, French, and Italian at:
http://www.bafu.admin.ch/wasser/01444/01995/index.html?lang=de
http://www.bafu.admin.ch/wasser/01444/08820/index.html?lang=de
http://www.bafu.admin.ch/wasser/01444/index.html?lang=de

The Federal Law on the Protection of Waters (WPL) applies to all surface and underground water (art. 2). The purpose of the law is to protect water against all harmful effects. In particular, it seeks to (art. 1):
a. maintain the health of persons, animals, and plants;
b. guarantee the supply and economic use of drinking water and water required for other purposes;
c. maintain the natural biotopes of indigenous fauna and flora;
d. maintain waters suitable for sustaining natural fish populations;
e. maintain waters as an element of the landscape;
f. ensure the irrigation of agricultural land;
g. permit the use of waters for leisure purposes; and
h. ensure the natural functioning of the hydrological cycle.

The Water Protection Ordinance (WPO) specifies the general regulations of the Federal Law on the Protection of Waters.

Art. 1 of the WPO: Purpose and principle
1 This ordinance shall facilitate the protection of surface and groundwater from harmful effects and enable their sustainable utilisation.

2 For this purpose, all measures taken under this Ordinance must take the ecological objectives of bodies of water into account.

Art. 2 of the WPO: Scope
This Ordinance regulates:
a. ecological objectives for bodies of water;
b. requirements on water quality;
c. evacuation of waste water;
d. evacuation of sewage sludge;
e. requirements on animal husbandry enterprises;
f. protection of water bodies in terms of area planning;
g. maintenance of appropriate amounts of residual water flow;
h. prevention of other harmful effects on bodies of water;
i. granting of federal subsidies.

1. Water governance at the national level

At the national level, the responsibilities for the implementation of the Federal Law on the Protection of Waters are the following (Art. 46 to 48):
Art. 46 WPL: Supervision and co-ordination
1 The federal authority shall supervise the enforcement of the present law.
2 The Federal Council shall regulate the co-ordination:
a. of the water protection measures of cantonal authorities;
b. between federal agencies;
c. between federal agencies and cantonal authorities.

Art. 47 WPL: Implementing regulations
1 The Federal Council shall enact the implementing regulations.
2 Before enacting the implementing regulations and while drafting agreements in international law, the Federal Council shall consult the cantonal authorities and interested parties.

Art. 48 WPL: Enforcement powers of the federal authority
1 In enforcing any other federal law or any international agreement, the relevant federal authority is at the same time responsible for the enforcement of the water protection law. Before enacting any decree which is based on this law it shall consult the cantonal authorities concerned and interested federal agencies.
2 The federal authority shall enforce the regulations on substances (Art. 9, para. 2, letter c.); it may request the co-operation of the cantonal authorities in performing parts of some of its duties.
3 The Federal Council shall determine which data concerning substances obtained on the basis of other federal laws shall be communicated to the Federal Office of Environment, Forests and Landscape.

2. Water governance at the NUTS 2 level (cantons)

The territory of Switzerland is divided in 26 cantons and semi-cantons. The cantons execute the regulations of the laws (WPL and WPO).
Art. 45 WPL
The cantonal authorities shall enforce the present law in all cases where Article 48 does not require enforcement by the federal authority. They shall enact all necessary regulations."

3. Water governance at the LAU level

The cantons may pass certain tasks involved in the application of the provisions of the law down to the community level.

Legislation on drought and water scarcity

Art. 33 WPO: Water withdrawals from watercourses

1 For withdrawals from watercourses (Article 29, WPL) which comprise sections with a permanent water flow and others without a permanent water flow, an authorisation is required if the site of the water withdrawal shows a permanent water flow. The conditions for granting the authorisation must be fulfilled only in the sections with a permanent water flow. (Article 30, WPL)

2 If the body of water at the site of water withdrawal shows no permanent water flow, the authorities shall ensure that the required measures under the Federal Law on Nature and Natural Habitat Protection of July 1, 196614 and on Fisheries of July 21, 199115 are taken."

Art. 43 WPL: Conservation of groundwater resources

1 Cantonal authorities shall ensure that over the long-term no more water is withdrawn from groundwater resources than flows into them. In the short-term more water may be withdrawn provided that this does not result in impairment of the quality of groundwater or of flora.

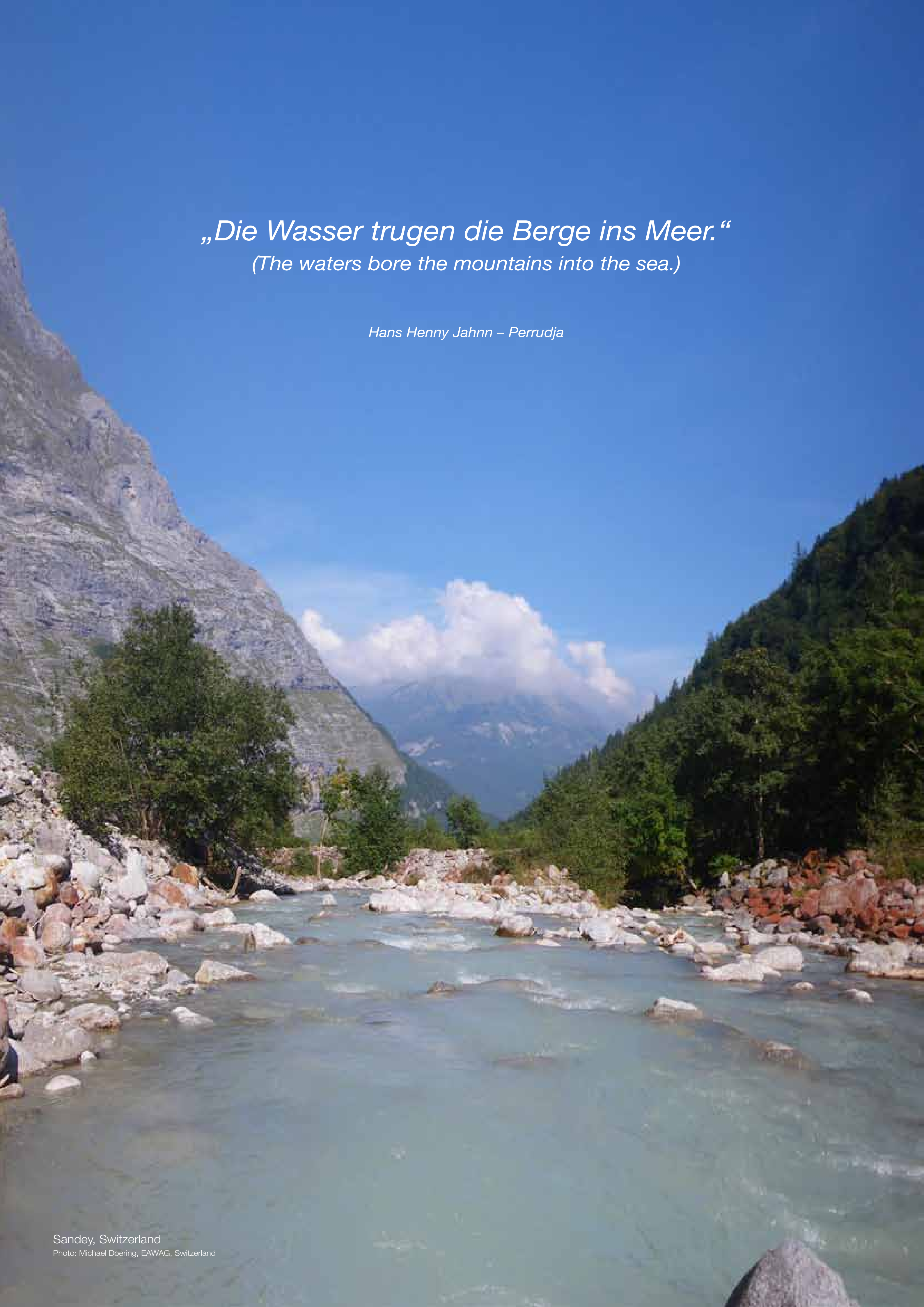
2 If a groundwater resource is impaired as a result of excessive withdrawal or through reduced inflow, the cantonal authority shall ensure that the situation is remedied as far as possible, either through reducing the rate of withdrawal or by artificial replenishment or by underground storage of drinking water.

3 Different groundwater resources shall not be connected to each other on a permanent basis if such a connection may result in impairment of the quantity or quality of the groundwater.

4 Storage volumes and flows of usable groundwater resources shall not be substantially reduced on a permanent basis as a result of new installations of any kind.

5 In cases of water damming installations with low storage levels, groundwater and flora which depend on the groundwater level shall not be substantially impaired. The authority may grant exceptions for existing installations.

6 Drainage of an area which results in a lowering of the groundwater table



Sandey, Switzerland
Photo: Michael Doering, EAWAG, Switzerland

Alp-Water-Scarce