MINISTERO DELL'AMBIENTE
E DELLA TUTELA DEL TERRITORIO E DEL MARE

THE ALPINE CONVENTION IS THE FIRST INTERNATIONAL TREATY FOR THE PROTECTION AND PROMOTION OF THE SUSTAINABLE DEVELOPMENT OF A CROSS-BORDER MOUNTAINOUS REGION

italian presidency 2013-2014
alpine convention

GUIDELINES ON LOCAL ADAPTATION TO CLIMATE CHANGE FOR WATER MANAGEMENT AND NATURAL HAZARDS IN THE ALPS

ALPINE CONVENTION

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Introduction

The role of mountains in the provision of indispensable 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[1]; Viviroli 2003, 2007, 2010). In particular, the Alps, with their seemingly vast water resources, are of immeasurable importance for the economic and social development of not only the Alps themselves, but also the lowlands and major urban areas. Although it may seem that drought events or water scarcity problems in the Alps have only occurred over short periods of time and in small, distinct areas in the past (PSAC 2009[2]), the severe droughts which affected much of Europe in 2003 also had a significant impact on the water resources of the Alpine regions. The creation of the European Drought Centre in 2005 can be seen as one of the results of this experience as well as communication by the Commission to the European Parliament and the European Council (EC 2007[3]) and several regional and local initiatives (e.g. drought committees in France). Efforts have been made not only on a legislative level to deal with the issue of water scarcity and droughts, but also on a scientific level, where many studies 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 facing an increase in anthropogenic water abstraction.

The impacts of climate change are likely to vary between the respective countries, not only because of the different locations within Europe, but also due to different national legislation and national circumstances in terms of availability and utilisation of water resources or vulnerability in terms of natural hazards.

Almost all countries of the Alpine Convention are in the stage of either deriving or having already adopted national adaptation strategies to climate change (http://climate-adapt.eea.europa.eu/web/guest/adaptation-strategies).

Apart from the national adaptation strategies there are some existing guidance materials and reports available covering different aspects of climate change adaptation for water resources management, such as for example:

a. ALPINE CONVENTION, PLANALP Platform: "Alpine strategy for adaptation to climate change in the field of natural hazards" (http://www.planat.ch/de/infomaterial-detailansicht/datum/2013/01/03/alpine-strategy-for-adaptation-to-climate-change-in-the-field-of-natural-hazards/)

b. UNECE Water Convention: Guidance on Water and Adaptation to Climate Change (http://www.unece.org/index.php?id=11658)

c. ICPDR Strategy on Adaptation to Climate Change (http://www.icpdr.org/main/activities-projects/climate-change-adaptation)

d. ICPR Reports on Climate Change in the Rhine catchment (Climate adaptation strategy is in preparation) (http://www.iksr.org/index.php?id=342&L=3&cHash=455fdab52ce6eafbf6f72632159564bf)

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

[2] PSAC (2009): Water and water management issues - Report on the state of the Alps. Permanent Secretariat of the Alpine Convention, Bolzano, 2009.

[3] 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.

The Italian national adaptation strategy to climate changes, currently subject to approval, identifies the Alpine area as a highly vulnerable sector due to critical impacts of human activities on environmental ecosystems, landscape and economy; special attention is paid to changes in water resources management (consumption and availability), which also involves effects for the downstream areas.

Vision: guidelines, overview and goal

The main goal of an adaptation strategy is minimising the risks connected to climate changes, protecting public health, life quality, properties and preserving nature, by improving the adaptation capability of natural ecosystems as well as social and economic systems; in addition, a solid adaptation strategy should be able to take advantage of new opportunities. As reported in *the White Paper*[4], the strategy tackling climate changes suggests two possible actions: 1) a reduction of greenhouse emissions with the objective of slowing down global warming (mitigation actions) and 2) an increase in the ecosystem's resilience and in human activities' resilience in order to tackle unavoidable impacts in the short terms (adaptation actions).

This document belongs to the second action; it aims in particular at defining guidelines, providing suggestions and criteria to adapt to climate changes related to water resources management and to natural hazards locally (at local scale). This is pursued in a context that encompasses both European and national legislations and local socioeconomic, environmental and climatic conditions.

4 White Paper "Adapting to Climate Change, towards a European framework for action", 2009 (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2009:0147:FIN:N:PDF HYPERLINK "http://bit.ly/clilima0 HYPERLINK "http://bit.ly/clima04")

Structure of local adaptation plans: key points (from risk assessment to specific actions)

Climatic enforcement, trends and future scenarios: climatic variability in the Alps

The Alps have been identified as one of the most vulnerable areas in relation to climate change in Europe. As outlined in the following studies, impacts due to climate changes had already been reported in the past:

- the temperature increase recorded in the Italian Alps in the last 30 years is three times the average increase registered in the entire boreal hemisphere (OECD, 2008; Alcamo, 2007); in particular, an increase of 2°C in the 20th century in the Alpine region is forecasted (Massarutto, 2011);
- time series of snow height recorded in 41 meteorological stations in the Alps and in the period 1920-2005 highlight a clear decreasing trend (Valt et al., 2005). This trend is even more evident in the last 30 years because of a decrease of snowfalls of 18% with respect to the benchmark period 1959-2002; a minimum decline of 40% has been registered at stations with low elevations.

Variations forecasted for future years can be summarised as follows:

- temperature: a continuous rise in the average temperature is foreseen (IPCC, 2007, BENISTON, 2005);
- rainfall: forecasted changes in long-term rainfall amount vary between the different Alpine regions, but due to changes in rainfall intensity and seasonal shifts extreme events are likely to become more intense, .i.e. a decrease in the rainfall amount, between -1 and -11% (Massarutto, 2011), and an increase in rainfall intensity is foreseen in the Italian part of the Alps (Brunetti et al.). Long-term average rainfall amount will remain more or less constant, but with seasonal shifts from the summer to the winter season in all Austrian regions (BMLFUW 2012);
- snowfall: the minimum snow line will increase; Foehn (1990) and Haeberli and Beniston (1998) claim that an increase in air temperature by 1°C will result in an increase by 150 m in the minimum snow line;
- water and ice: continuous increase in water temperature as well the thawing of permafrost in wide areas (Massarutto,2011); significant increase of flows in winter (up to 20%) and decrease of flows in summer (-20%) (CLIMCHALP WP 5, 2007); increased frequency in droughts and frequency and intensity of negative extreme events; melting of glaciers (Massarutto,2011);
- nature: migration of flora and shift of tree line (Massarutto, 2011); loss of biodiversity (IPCC, 2007).

Impacts and vulnerability

The impacts of the climatic changes mentioned above can be classified in two types: physical-biological and socio-economical. The first type of impact can be further classified into 1. impact on mountain forests, 2. impact on biodiversity and ecosystems; 3. impact on water resources; 4. extreme meteorological events triggering natural hazards; 5. soil conservation. The socioeconomic impact can be further classified into the following subclasses: 1. urban planning; 2. energy; 3. tourism; 4. mountain agriculture; 5. transportation; 6. public health. The following part of the document will focus on impacts on water resources.

Impact on water resources

Impact on water resources due to climate changes can be classified as follows:

- changes in precipitation regimes, an increase in the snow line and a progressive loss of ice mass bring about a variation of the flow regime in Alpine torrents, consisting of a reduction in the summer discharge and an increase in the winter discharge, which is likely to result in an increase of flood hazard (Lautenschalger et al., 2008) and a decrease of water availability for agricultural activities and human consumption during summer (Weingartner et al., 2007).
- in the last 130 years, rainy days have decreased whereas dry days seem to have increased by 2 units per century (Lionello et al., 2009). Lehner et al. (2006) and Giannakopoulos et al. (2009) estimate that drought events will be twice more frequent in 2050 than now and three time more frequent in 2070. The increase in air temperature is accelerating glacier melting and permafrost degradation, and as a consequence, fresh water resources will be reduced and slope instability will increase (Mercalli et al., 2009 e Margottini et al., 2007). Zemp et al. (2006) estimates that an increase in the average air temperature by 3˚C in summer can cause a decrease in glacier cover, i.e. by 75% in the Italian Alps.
- Van Vliet et al. (2012) claim that both in mountain torrent environment (streams and rivers) as well as in lakes and humid areas climate changes are causing an increase of water temperature; this, in addition to other secondary impacts, can deteriorate water quality and cause further problems for the ecosystem. In the large Alpine lakes, (such as Lake Maggiore, Lake Iseo, Lake Garda and Lake Como) the water temperature has increased roughly by 0,1-0,3°C every decade since the 1950s (Dokulil et al., 2006). In future decades greater additional rises are expected; for Alpine lakes this increase will be presumably higher in the superficial layers than in the deeper layers. This is likely to bring about a thermal stability, which will result in a weaker vertical water circulation (Peeters et al., 2002), which, in turn, will reduce the oxygen available in the deep layers and, as a consequence, the chemical water quality.
- the higher intensity in precipitation is likely to induce an increase in erosion processes and, as a consequence, an increase in the nutrient and sediment transport in streams and rivers (Garnier M., 2007).
- also evaporation is affected as a migration of flora and shift of the tree line is expected (Massarutto, 2011).

These findings are – with some regional differentiation and fine-tuning – mirrored in the national adaptation strategies (e.g. BMLFUW 2012).

Finally we would like to remind that local downscaling of rainfall predictions provided by climate model is crucial for the assessment of climate change impacts on hydrological processes, because the presence of bias in downscaled precipitation may produce large bias in the assessment of soil moisture dynamics, river flows and groundwater recharge (Portoghese et al., 2010). Some methodologies have been set up in order to reduce the bias.

Impact on natural hazards

The main impacts of climate changes on natural hazards can be summarised in the following points:

- climate change could cause a drift of the great atmospheric conditions on European scale: this could cause extreme weather conditions in certain parts of the Alps like heavy snowfalls, precipitations or droughts, that are difficult to forecast.
- steep permafrost areas are likely to become unstable and more prone to rockfalls and landslides (Margottini et al., 2007). Depending on the volumes of the mass involved in the thawing, on the potential energy, rockfalls can result in debris or icy avalanches, characterised by high propagation velocity and run-out potential. Therefore, permafrost degradation contributes to an increase of landslide processes (Gruber et al., 2004).
- Fuhrer et al. (2006) claim that the Alpine region, despite the differences between the north and south territory, will experience an increase of extreme events in winter, with subsequent risks in several fields (Beniston, 2007).
- the acceleration of the Alpine glaciers retreat (both in terms of area and volumes) is associated with a rapid release of sediment and debris (Davis et al., 2001). The phenomenon tends to modify the morphological and dynamical characteristics of the glaciers, creating the triggering conditions for successive geological instability situations, especially in the steepest slopes (Diolaiuti e Smiraglia, 2012).
- massive quantities of water and debris could be released by glacial lakes and non-consolidated moraines that could move downslope after the melting of the ice walls currently containing them (Smiraglia et al., 2008; Tamburini et al., 2009);
- snow avalanche hazard may probably decrease in frequency and intensity at medium-low elevations, in particular new-snow avalanches; wet-snow avalanches, on the other hand, may probably increase.
- infrastructures located at high elevations (shelters, cable car stations) may be subject to basis destabilisation due to permafrost degradation; mountaineers approaching elevated zones may be endangered because of the increased slope instability (see PermaNET project);.
- climate change may also have an impact on transportation infrastructure, especially streets or railways that connect mountain passes (see Paramount project).

Policies and adaptation measures

Because of the differences in expected impacts of climate change across the different Alpine countries a “one size fits all”- approach cannot be recommended. Therefore, a catalogue with a non-exhaustive list of potential measures/actions, which could be selected according to specific regional needs, will be proposed. Potential measures/actions will have to be tailored to the regional needs.

Potential actions for the management of the water resources

Based on the impacts described above, it is foreseeable that climate change will affect both the demand of water resources, which will increase and become more rigid and vulnerable with different characteristics across countries, and on the water availability, which will become more aleatory and will probably decrease. Furthermore, it is foreseeable that the

requests for defence of the environment and of the ecosystem will become more pressing and demanding in order to guarantee human health, the equilibrium of the ecosystem and the prevention of natural hazards.
It is thus necessary to reduce the expected impacts and to increase the resilience of human activities. Therefore, adaptation actions must be carried out. These potential actions may be divided into:

1. infrastructural and technological measures ("grey" measures): these potential measures generally include mitigation structures, efficiency-improving interventions, monitoring actions or the implementation of decision support systems for a timely response to extreme events;
2. ecosystem-oriented measures ("green" measures): these measures are about environmental and fluvial requalification interventions;
3. non-structural interventions ("soft" measures): these actions include the increase of knowledge through research, legislative and planning processes, communication tools aimed at increasing consciousness and at influencing lifestyles of people. In the following pages a list of strategic adaptation actions will be given, on the basis of what was originally proposed by the Italian Ministry for the Environment, Land and Sea,[5], the Lombardy Region[6] and CIPRA Italy[7], and subsequently discussed and shared with the delegations of the different Alpine countries.

Potential "grey" measures

1. Optimising use of the available water resources (adjustment of the offer, where appropriate, efficient irrigation, conservative agricultural system to increase water storing capacity, where needed, prevention of soil erosion, optimisation of distribution systems).
2. Structural interventions aimed at updating water pipelines and reducing water leakages.
3. Strengthening of the current methods for monitoring the status of surface and ground water resources.
4. Empowering of the current monitoring systems of water resource at high elevation (especially the snow-water equivalent).
5. Improving the current database and predictions of water consumptions and of run-off volumes.
6. Strengthening the interregional exchange of data and monitoring systems.
7. Technological upgrade of the measuring systems (e.g. remote sensing...), where appropriate.

5 Elementi per una Strategia Nazionale di Adattamento ai Cambiamenti Climatici, documento per la consultazione pubblica, 12 settembre 2013 (Italian Ministry of the Environment: public consultation process towards a National Strategy of adaptation to climate change - http://www.minambiente.it/sites/default/files/archivio/comunicati/Conferenza_29_10_2013/Elementi%20per%20una%20Strategia%20Nazionale%20di%20Adattamento%20ai%20Cambiamenti%20Climatici.pdf)

6 Linee Guida Piani di Adattamento ai Cambiamenti Climatici, Regione Lombardia (towards a regional adaptation strategy in Lombardy - http://www.reti.regione.lombardia.it/cs/Satellite?c=Redazionale_P&childpagename=DG_Reti%2FDetail&cid=1213581345956&pagename=DG_RSSWrapper)

7 Antonio Massarutto, Acqua e cambiamenti climatici, compact n. 03/2011, CIPRA Internationale Alpenschutzkommission (http://www.cipra.org/it/pubblicazioni/4807)

Potential “green” measures

1. Requalification of the rivers taking into account the minimum vital flow (MVF) and the ecological status;
2. Creation of buffer zones between rivers and cultivated areas, where appropriate;
3. Protection and restoration of wetlands, not only in the riparian zones, but also more widely;
4. Restoration of the ecological integrity of the riparian and lateral area (transition zones) of the rivers, where possible, in order to strengthen their role of regulation in biogeochemical processes: a) Assuring protection of the area connected to water; b) minimising the disturbance associated with the uptake and release of water from hydropower plants; c) reactivation of the relict fluvial forms, where possible;
5. Multipurpose management of existing reservoirs.

Potential "soft" measures

Legislation and planning	1. Development of a multiannual management attitude towards water resources, where not considered yet; 2. Recalculation of historical water requirement and water grant, where appropriate; 3. Development of an integrated programme for improving the efficiency of irrigation, optimised consumption of drinking water and industrial usage; ensuring the minimum vital flow (MVF) taking into account climate change predictions.
Management	1. Creation of flood and, where appropriate, also drought management plans. Ensuring the attainability of water resources management objectives in case of severe drought and the design of a *warning system* based on the expected most frequent water scarcity (LAWA, 2007). 2. Ensuring progressive compliancy with the legislation on MVF and on the water quality standards based on the 2000/60 EC directive. 3. Optimisation of lake level management, where appropriate. Efficient water management in the irrigation sector. 4. Creation of plans for the management and utilisation of urban run-off, where appropriate. 5. Use of stored rainwater, joint use of resources with other big users, reuse of water (e.g. for toilet flushing or watering the garden).
Communication – Dissemination / Participation	1. Collection and dissemination of available information on climate change. 2. Dissemination of information on the existence of good practices in agriculture, in the domestic sector and in industry through stakeholder cooperation. 3. Promotion of events for awareness raising in the area affected by the variation of the hydrological cycle (extreme events, drought, high run-off variability, etc.), e.g. extension and strengthening of participation with negotiation tools and increase of protection measures for available water in the mountain territory.
Economy / incentives	1. Definition of incentives for products characterised by efficient water usage and/or high water quality level (grey water), where appropriate. 2. Planning of economical tools for the management of climatic risk (insurance, etc.), where feasible.

Potential research questions:

1. Monitoring of the environmental indicators and comparison to the actual values used to assess the reference sites.

2. Improving the database for surface and ground water availability in order to obtain more

reliable estimates on the resistance of the resources.

3. Improving comprehension of continuous feedback and the impact that the variation of climate (temperature and precipitation pattern) may have on soil moisture, ecology and vegetation.

4. Improving knowledge about paths and weather conditions of extreme rainfall events.

Potential actions for the management of natural hazards

As for the actions proposed in the context of water management, this chapter provides a catalogue with a non-exhaustive list of potential measures, which could be selected according to specific regional needs.

In Alpine areas, natural hazards represent one of the biggest threat to human life, the integrity of infrastructures and belongings. The actual hazard is sometimes exacerbated by the provision of infrastructure or urban expansion in hazardous zones and by the increase of extreme events due to climate change. As some hazards (e.g. glacial and hydrogeological hazards) may interact in a synergic way as a reaction to meteorological events (heat waves or intense precipitation), the integrated and interdisciplinary management of natural hazards has become a crucial priority in the adaptation strategies of most Alpine countries (AdaptAlp, 2011). The adaptation actions that may help in this context have been divided into three different classes: “grey”, “green” and “soft” measures as described below.

Potential “grey measures”

1. Construction of additional mitigation structures to assure the security of hazardous zones.
2. Strengthening of the current monitoring network of the phenomena through the installation of meteorological stations (containing rain gauges, thermometers and snow height sensors) in (small) basins considered to be prone to extreme events.

Potential “green” measures

1. Enlarging the space for rivers and restriction of soil pavement in order to save the natural capacity of the riverbanks to balance the discharge peak;
2. Promotion of the recovery for mountain farming zones (e.g. terraces on the slopes) and ensuring correct maintenance of mitigation structures;
3. Privileged use of natural protection systems (e.g. water retention basins) if adding supplementary mitigation structures is necessary.

Potential “soft measures”

Planning	1. Continuous update of cartography in relation to hazard maps by adding observations on climate change. 2. Identificaiton of the most critical areas subject to natural hazards and climate change. 3. Increased use of territorial planning in order to reduce the demand of new infrastructures in hazardous zones and subsequent decrease of the vulnerability of the system.

Management	1. Reinforcement of the natural hazards management with the use of a multi-risk analysis. 2. Upgrading of the current alert/alarm systems and the emergency procedures, due to the increase of frequency of extreme meteorological events.
Communication – Dissemination / Participation	1. Assuring continuous education and training on natural hazards directed at the population living in the mountains. 2. Increase of people's consciousness with respect to the main natural hazards and the residual risk. 3. Promotion of insurance systems on natural hazards. 4. Promotion of communication events directed at house owners on the type of hydraulic risk and on mitigation structures. 5. Promotion of the exchange of experiences and good practices (e.g. PLANALP database, PLANAT of Switzerland). 6. Promotion of cooperation with stakeholders. 7. Assuring transparent sharing of monitoring data, of the terminology and of the calculation methods of the integrated risk in the Alpine regions.

Potential research questions:

1. Reduction of the uncertainties in relation to the most critical risks, to the highest impacts and future predictions due to the glacial retreat.

2. Improving the basis for the evaluation and monitoring of natural hazards management actions, in cooperation with other Alpine countries.

3. Assuring assimilation of future climatic projections in hydrological models in order to improve the knowledge about mechanisms behind the increase of intensity and frequency of natural hazards in mountainous zones.

4. Assessing real-time monitoring and prediction systems for risk management.

5. Validation and integration of a meteorological radar analysis with the meteorological sensor network.

European projects

AdaptAlp[8]

Detecting climate-related trends in hydrological datasets is important in order to investigate the water resources in Alpine catchments. The recognition of this trend should be based on a reliable dataset of homogenous hydrological datasets representing undisturbed catchments. The project AdaptAlp aims at detecting trends in hydrological regimes of Alpine catchments based on a dataset of 177 run-off time datasets all over the Alpine space (see Figure 1). These series cover forty years of daily records. As a consequence, a set of hydrological indices is defined to characterise the hydrological regime in terms of low, medium and high flow. In particular, these indices describe the drought severity and seasonality, as well as the intensity and timing of snow melt flows. The work carried out by AdaptAlp partners led to capturing a hydrological dataset used to determine climate-related trends in the hydrological regime of Alpine catchments.

Statistical tests were applied to the stations of this dataset at the local and regional scales. The main significant trends can be summarised as follows:

• **Winter droughts**:
- Severity of drought tends to decrease for glacier and snow melt-dominated regimes.
- A slight shift (forward) is identified for snow melt and composite regimes in the Northern Alps.
- Mixed snow melt-rainfall regimes in the South-Eastern Alps (mostly Slovenian stations) show the opposite development: severity of drought tends to increase and seasonality seems shifted backwards.

• **Snow melt-related high flows** in spring
- An increase in the volume and a peak of snow melt flows is observed for glacier regimes.
- An increase in the duration of the snow melt season is observed for snow melt regimes, along with an earlier beginning of the snow melt season.

• **Medium flows**:
- Glacier regimes show an increasing annual flow and an increasing base flow index.

The consistency of observed trends at least suggests that the changes are unlikely to be linked to measurement issues, but are more likely climate-related.

8 www.adaptalp.org

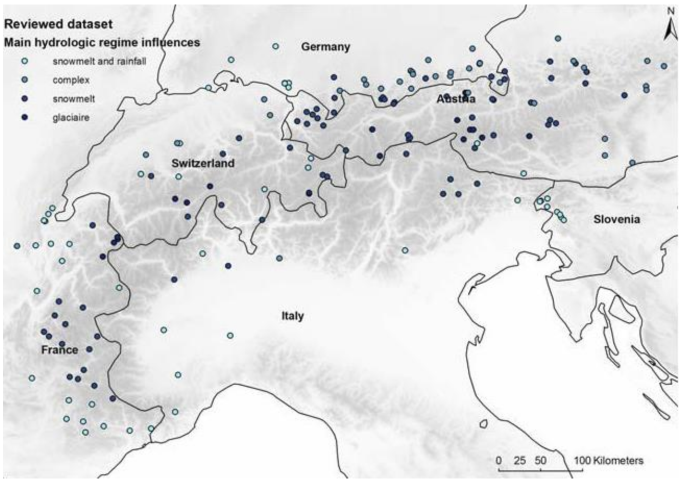

Figure 1: The AdaptAlp dataset (2011).

C3-Alps[9]

C3-Alps is a transnational capitalisation project. Based on the results of previous projects and initiatives on adaptation to climate change in the Alps, C3-Alps tries to synthesise, transfer, and implements the best available adaptation knowledge into policy and practice.

Within the project a paper on the impact of climate change scenarios on water resources management in the Italian Alps was published (Ranzi et al., 2009). The paper deals with the simulated run-off in the current and future climate scenarios in two Alpine basins in Northern Italy relevant for irrigation, water supply and hydropower. The results say that in spite of a slight increase of precipitation, a decrease of about 5% of run-off volume for the 2050 scenario, and of 13% for the 2090 scenario was estimated at the outlet of the two basins because of the higher evapotranspiration losses. Same changes in energy generation are expected for the hydropower plants.

Clisp[10]

CLISP (Climate Change Adaptation by Spatial Planning in the Alpine Space) is a transnational European project funded by the Alpine Space Programme under the European Territorial Cooperation 2007- 2013. 14 project partners from six different Alpine countries tackled the challenges that spatial development and spatial planning are facing due to climate change.

The potential impacts investigated are on flood-prone areas, avalanche-prone areas, rockfall- prone areas, torrential-process-prone areas. The adaptive capacity consists of the application of the directives (e.g. with the Flood Directive 2007/60/EC) in order not to increase the extension and number of hazardous areas.

As far as water management is concerned, the potential impact suggests that climate change is likely to reduce water availability due to more frequent aridity and drought, more

[9] http://www.c3alps.eu/index.php/it/
[10] www.clisp.eu

concentrated precipitation events and higher temperature, which will in turn shift precipitation from snow to rain and reduce snow storage. The adaptive capacity entails the adoption of structural measures targeted at increasing the water storage capacity in catchments, as well as non- structural measures including more efficient water use, water conservation and appropriate land management. In this context, the River Basin Management Plans, which will be formulated according to the Water Framework Directive (2000/60/EC), represent a context, in which a number of planning and management instruments are being developed and coordinated for adaptation.

Alp-Water-Scarce[11]

The work carried out within the "Alp-Water-Scarce" project (1/10/2008 – 31/10/2011), funded by the EU Alpine Space Programme, has resulted in a set of recommendations which are based on case studies performed on the different pilot sites (Hohenwallner et al., 2011). What these recommendations have in common is the need to preserve the water resources of the Alps for future generations, to meet increasing water demand and to cope with climate change-induced stress. The strong commitment of public bodies to cooperate on 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 tackle water scarcity.
Within Europe, agreements for such transboundary water management exist for the main river basins of the Danube, the Elbe, the Meuse, the Mosel, the Oder and the Rhine. These agreements have definitely also an impact on the Alps since they are the point of origin of some of these river systems. The technical solutions proposed are:

- increasing the efficiency of the supply network (minimising water losses);
- optimising 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 instead of deviation of surface water or artificial groundwater recharge.

Alpstar Project[12]

Temperatures in the Alps have risen almost twice as much as the global average over the last century. And they are supposed to rise even more, especially if the Alps themselves continue to consume around 10% more energy per capita than the European average. However, clever and innovative adaptation or mitigation initiatives are increasing in local and regional Alpine areas facing climate change consequences. The challenge is thus to make best practice become minimum standard if we want climate neutrality in the Alps be achieved within the next 40 years. Here is the aim of the Alpine Space project *"Alpstar. Toward Carbon Neutral Alps – Make Best Practice Minimum Standard"* through the collection, analysis, comparison, testing and implementation of climate protection measures in 12 pilot regions all the over the Alps.
The main objective of the Alpstar Project is to encourage the activation, diffusion and implementation of proven good practice measures in order to reduce climate change and

[11] http://www.alpwaterscarce.eu/
[12] http://alpstar-project.eu/

prepare cross-sectorial strategies and action plans with respect to carbon neutrality on regional and local level. The specific objectives are the following:

- Encouraging and supporting exchange of experiences, knowledge and know-how among pilot regions in order to facilitate their implementation and to use and spread local strategies and good practices for the reduction of GHG emissions.
- Searching for good practices in preparation and implementation of strategies, action plans and measures with respect to carbon neutrality and to make them become minimum standard.
- Improving transboundary, cross-sectorial and inter-policy level cooperation in coping with climate change.
- Promoting integrative and participatory approachees in development of cross-sectorial strategies and action plans and implementation of measures with respect to carbon neutrality.
- Empowering local and regional administrative actors and planners to become facilitators of a change process.
- Encouraging pooling, transfer and implementation of innovative and efficient good practices from and to other Alpine regions and beyond.

National initiatives

StartClim2005.A4[13] (Austria)

The document deals with the emergencies caused by extreme events in drinking water supply in Austria. To assure water supply during extreme events, several different arrangements should be made. These arrangements are: disaster preparedness (organisational and technical arrangements), provisions at imminence, and a crisis and disaster management in case of emergency (drinking water emergency supply, information policy and cooperation with the media, collaboration with crisis and disaster management groups).
The comparison of different national concepts has shown that these concepts of water suppliers strongly depend on the support by the federal states (e.g. financial support).

Mountland[14] (Switzerland)

Mountain regions provide essential Ecosystem Goods and Services (EGS). Global change, however, puts the capacity of mountain ecosystems for the provision of key services at risk. The “Mountland” project, coordinated by the Swiss Federal Institute for Forest, Snow and Landscape Research WSL, focuses on three case study regions in the Swiss Alps and aims at proposing sustainable land-use practices and alternative policy solutions to ensure the provision of EGS under climate and land-use changes.

In “Mountland” an integrative approach is applied, combining methods from economics and political and natural sciences in order to analyse ecosystem functioning from a holistic human-environment system perspective.

The first part of the project deals with sustainable land-use practices in mountain regions, through an integrative analysis of ecosystem dynamics under global change aimed at deriving socio-economic impacts and policy implications.

The second part of the project deals with the prioritisation for adaption to climate and socio-economic changes, backcasting tolerable future states to match supply and demand for ecosystem services in mountain areas.

HydroAlp[15] (Italy)

In Italy, the research centre Eurac wrote a report on climate[16] dealing with the impacts of climate change on temperature, water resources (snow precipitation, glaciers), extreme events, natural vegetation and on human activities, such as agriculture, water management, health and tourism. The adaptation consists firstly in climate preservation and subsequently in defining strategies to mitigate the inevitable consequences. The scientific approach allows to estimate the physics of the changes in order to be better prepared to respond. The

13 http://www.austroclim.at/index.php?id=45
14 http://www.wsl.ch/fe/walddynamik/projekte/mountland_home/index_EN
15 http://www.eurac.edu/en/research/projects/ProjectDetails.aspx?pid=9221
16 Eurac Research: Rapporto sul clima. Alto Adige

possible actions to mitigate climate change impacts on water are:

- Saving and reducing water consumption;
- Collecting water in basins;
- Implementing a more recent and better monitoring system and forecasting the availability of water with appropriate management plans.
- A project called Etsch Dialogue aims at recreating the complete equilibrium of the upper fluvial area of the Adige river via a dialogue between the different water users and the cooperation of the local population.

Irri4Web[17] (Italy)

A decision support system for irrigation scheduling is proposed as a tool for improving agriculture sustainability and adaptation to the ongoing climate change. In the Autonomous Province of Trento (Italy), the newly implemented Public Waters General Exploitation Plan fixes new ceilings to the use of irrigation water and aims at its optimisation by setting up limits to soil moisture. The protocol entails the assessment of water content in a soil parcel, on the basis of its location and the history of the latest irrigation actions. The water balance is determined with rainfall and temperature values spatially interpolated and retrieved from the neighbouring meteorological stations (see Figure 2: the experimental area in the Non Valley). The Hargreaves equation (Hargreaves and Samani, 1985, Battista et al., 1994) is used for the calculation of evapotranspiration, and pedologic information is gained from a "(pedo-) landscape map" compiled for this purpose. An estimate of soil water content is provided to end users. Soil water content is calculated from 7 days before to 3 days after user's request. Weather forecasts are provided by the local weather service. The system is currently ready for its distribution to farmers and agricultural syndicates.

[17] http://meteo.iasma.it/irri4web/

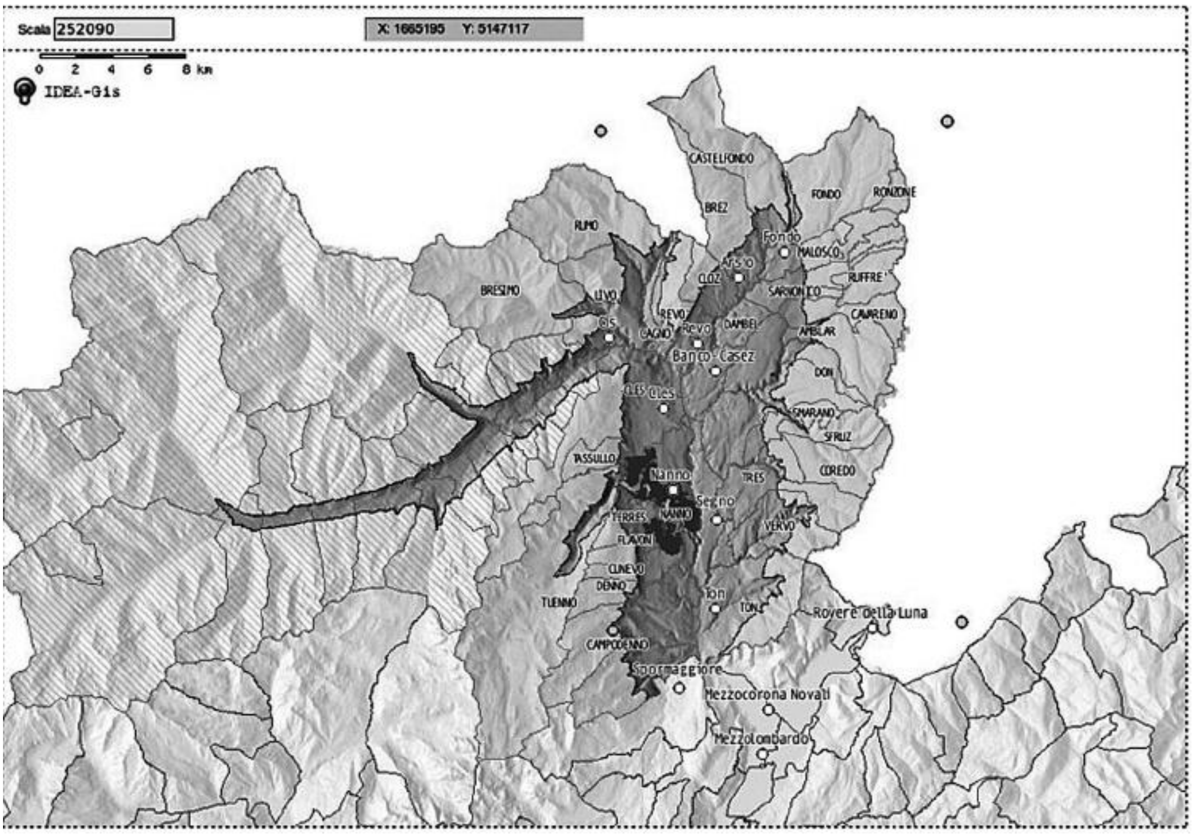

Figure 2: Experimental area of irri4Web (Zottele et al., 2014)

Bavarian climate adaptation strategy – BayKLAS (Germany)

In 2009, Bavaria launched the Bavarian climate adaptation strategy – i.e. the BayKLAS project. It aimed at pursuing new policies about water management, agriculture, forestry, nature conservation, soil conservation and geological risk, health, civil protection, regional planning, urban, town and country planning, road building and traffic planning, energy sector, industry and trade, tourism and finance sector. Even if in Bavaria no holistic local adaptation plans for single municipalities are set up, this programme and adaptation strategy lead to on-site measures in the municipalities.
Three examples are given below:

1) **Mountain Forest Initiative** [18]

A special set of measures known as the **"Mountain Forest Initiative**" (Bergwaldoffensive, BWO) focuses on the adaptation of the Alpine forests in Bavaria to climate change. The central aim of the BWO is to stabilise and sustainably adapt the Alpine mountain forests to climate change. For this purpose, 30 projects were identified in areas with special climatic risks. Integrated master plans were developed for these projects, which include different silvicultural measures like thinning, planting and natural regeneration, the construction of forest roads, and hunting and pasture management for the reduction of browsing damage. A large number of owners are usually affected by the projects. Thus, the pilot measures are planned and initiated in agreement with the land owners and local stakeholders. This strong focus on participation renders the process transparent – a crucial factor for the success of the projects. Other important elements of the BWO include improving the supply of suitable tree seeds for the Alpine region in Bavaria, strengthening also applied research and generating new basic information for the management of Alpine forests. For example, a digital map of forest soils in the northern Alps was generated as a basis for restoration and forecasts by the WINALP project (Waldinformationssystem Nordalpen) in cooperation with partners from Austria (Tyrol, Salzburg).

[18] Alpine strategy for adaptation to climate change in the field of natural hazards – PLANALP 2013
www.forst.bayern.de
www.hswt.de

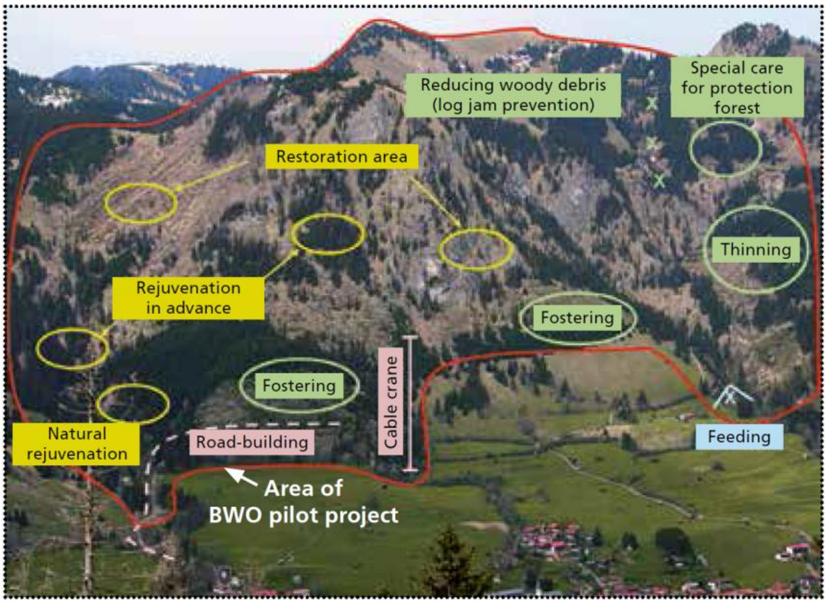

Figure 3: Example of measure combination within a Mountain Forest Initiative Area (Bavarian State Institute of Forestry).

2) Additional climate factor for hydraulic structures

The design flood for flood protection measures (like dikes) in Bavaria has a return period of 100 years.
Even if no accurate prediction about a future change in the 100-year flood is possible, experts assume that there is an increase of the discharge for 100-year flood events. Therefore, since 2009, Bavaria has been using an additional climate factor of about 15% in case of the 100-year flood and 7,5% in case of the 200-year flood (see **Error! Reference source not found.**). For new constructions of flood protection the design discharge is increased by this factor.

Figure 4: An example of design flood, considering climate change.

3) Drinking water supply: taking precautions against drought

Investigations about the water supply structure in Bavaria showed that about one third of the 2,800 water supply facilities has no alternative supply possibilities. The existing regional and foreseeable seasonal imbalance in the distribution of precipitation in Bavaria calls, in particular, for an increase in secure supplies of drinking water on local and regional level by networking plants or through alternative water production facilities, especially in those parts of Franconia and of the Upper Palatinate Forest and the Bavarian Forest that have water shortages. This also applies to climate change. Some case studies showed that about 3% of the water supply facilities of the investigation area are subject to degradation with respect to ensuring consumption due to climate change.

Programme NRP 61: Sustainable Water Management (Switzerland)[19]

The research programme NRP 61 "Sustainable Water Management" of the Swiss National Science Foundation set the goal to provide a basis for sustainable water management in Switzerland. As part of this research programme the effects of climate and socio-economic changes on water availability, water use and water management were investigated in the Crans-Montana-Sierre region, situated in the dry inner-Alpine Valais (MontanAqua project). The project followed an inter- and transdisciplinary approach; stakeholders were involved from the very beginning.

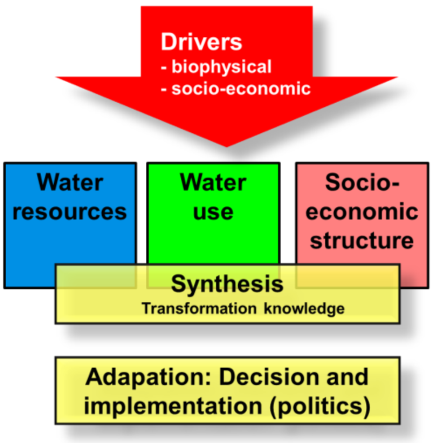

Figure 5: The inter-and transdisciplinary approach of the project.

We assessed the current water situation with quantitative and qualitative methods: A dense hydrometeorological network was built up, tracer experiments were conducted and communal water uses as well as the current water management system were analysed.

[19] Weingartner, R., Reynard, E., Graefe, O, Liniger, H., Rist, S., Schädler, B., Schneider, F., Effects of climate and socio-economic changes on water availability, use and management at the regional scale – a case study in the dry inner-Alpine zone of Switzerland

These investigations paved the way fordeveloping models in order to simulate possible changes in the immediate and more distant future. For this purpose, we used existing regional climate change scenarios and developed socio-economic scenarios together with the stakeholders.

The findings of MontanAqua can be summarised in five messages, each with a short recommendation:

1 – The socio-economic changes have a greater impact on the water situation in 2050 than the climate change: A territorial development that limits water needs is recommended. This requires important changes of current water and land-management practices.

2 – The water quantities available now and in 2050 are generally sufficient. However, shortages are possible in some areas and seasonally: We recommend establishing regional water management which goes beyond the development of technical infrastructure such as storage facilities or connections between water supply networks. This measure should be accompanied by clarification and negotiation of water rights at the regional level.

3 – Water issues are primarily regional management problems: We support a better cooperation between the eleven municipalities of the region and the establishment of a demand management strategy which is aimed at coordinating use and reduction of water needs.

4 – Intercommunal measures on infrastructure can help to ensure sustainable water supply, provided that they are integrated into ambitious institutional reforms: A more equitable water management at the regional level requires a renegotiation of management principles and access rights to water resources.

5 – To achieve sustainable regional water management improved data management and transparency is needed: We recommend that the Canton of Valais should develop a strategy for monitoring water at the regional level and for the collection of homogenised data. We also recommend the assessment of the current water management at the regional level in terms of sustainability. Finally, we promote the launch of a study in order to clarify the water rights.

References

Alcamo, J.; Floerke, M.; Maerker, M., 2007. Future long-term changes in global water resources driven by socioeconomic and climatic changes. Hydrological Sciences Journal.

Alpine Convention, PLANALP Platform. Alpine strategy for adaptation to climate change in the field of natural hazards" http://www.planat.ch/de/infomaterial-detailansicht/datum/2013/01/03/alpine-strategy-for-adaptation-to-climate-change-in-the-field-of-natural-hazards/

Bard, A., Renard B., Lang, M. The AdaptAlp Dataset 2011 UR HHLY Hydrology-Hydraulics 3 bis quai Chauveau CP220, F-69336 Lyon, France

Barnett T.B., Adam J.C., Lettenmaier D.P.. Potential impacts of a warming climate on water availability in snow-dominated regions. Nature, 438: 17. 2005

Battista P., Benincasa F., Duce P., Pellizzaro G., 1994. Metodi Agrometeorologici per il calcolo dei fabbisogni irrigui. Quaderno Ce. S.I.A., 30, 91 pp.

Beniston, M., 2007. Linking extreme climate events and economic impacts: Examples from the Swiss Alps. Energy Policy 35: 5384–5392.

Beniston M.(June 2005), Climatic change and its possible impacts in the Alpine region, in: Revue de Géographie Alpine, Tome 93, n° 2,pp.19-32.

Beniston, M.; Stephenson, D. B.; Christensen, O. B.; Ferro, C. A. T.; Frei, C.; Goyette, S.; Halsnaes, K.; Holt, T.; Jylhü, K.; Koffi, B.; Palutikoff, J.; Schöll, R.; Semmler, T. and Woth, K., 2007: Future extreme events in European climate: An exploration of regional climate model projections. Climatic Change 81: 71–95.

BMLFUW (2012): Austrian Strategy for Adaptation to Climate Change. Federal Ministry of Agriculture, Forestry, Environment and Water Management (http://www.bmlfuw.gv.at/umwelt/klimaschutz/klimapolitik_national/anpassungsstrategie/strategie-kontext.html)

Brunetti, M., Maugueri, M., Monti, F., Nanni, T., 2006. Temperature and precipitation variability in Italy in the last two centuries from homogenised instrumental time series. Int. J. Climatol.

CLIMCHALP Project Work Package 7 (2008), Impacts of Climate Change on Spatial Development and Economy; Synthesis & Model Region Studies

Diolaiuti, G., Bocchiola, D., D'agata, C., Smiraglia, C., 2012: "Evidence of climate change impact upon glaciers' recession within the Italian Alps". Theoretical and Applied Climatology, 109: 429--445.

Dokulil, M. T., Jagsch, A., George, G. D., Anneville, O., Jankowski, T., Wahl, B., Lenhart, B., Blenckner, T. and Teubner, K., 2006. Twenty years of spatially coherent deepwater warming in lakes across Europe related to the North Atlantic Oscillation. Limnology and Oceanography 51, 2 787–2 793. doi:10.4319/ lo.2006.51.6.2787.

Foehn, P. (1990), Schnee und Lawinen, Schnee, Eis und Wasser der Alpen in einer wärmeren Atmosphäre (ed D Vischer). Mitteilung der Versuchsanstalt fuer Wasserbau, Hydrologie und Glaziologie der ETH Zürich, 108, 33?48.

Fuhrer J.; Beniston, M.; Fischlin, A.; Frei, C.; Goyette, S.; Jasper, K. and Pfister, C.: Climate risks and their impact on agriculture and forests in Switzerland. Climatic change 79, pp. 79–102, 2006.

Garnier, M., Passarella, G., Lo Porto, A., 2007. Impatto del cambiamento climatico su erosione e perdita di nutrienti dal suolo agricolo nel bacino dell'Enza. Clima e Cambiamenti Climatici: Le Attività di Ricerca del CNR, Roma - ed. Dipartimento Terra E Ambiente – CNR 581-584

Giannakopoulos, C., et al., 2009. Climatic changes and associated impacts in the

Mediterranean resulting from a 2 °C global warming, Glob. Planet. Change.
Gruber, S., Hoelzle, M., Haeberli, W., 2004. Permafrost thaw and destabilization of Alpine rock walls in the hot summer of 2003. Geophysical Research Letters, vol. 31
Gruber, S., Hoelzle, M., Haeberli, W., 2004. Rock wall temperatures in the Alps, Permafrost Periglacial Processes, in press.
Haeberli, W., and M. Beniston (1998), Climate Change and Its Impacts on Glaciers and Permafrost in the Alps, Ambio, 27(4), 258-265.
Hargreaves, G.H., and Z.A. Samani. 1985. Reference crop evapotranspiration from temperature. Applied Engrg. in Agric. 1:96-99.
Hohenwallner D, Saulnier GM, Castaings W, Astengo A, Brenčič M, Bruno C , Carolli M, Chenut J, De Bona A, Doering M, Dutto E, Freundl G, Harum T, Jamsek A, , Klemenčič-Kosi S, Kopeinig C, Klug H, Lascours S, Maiolini B, Mignone N, Neuwirth J, Paccard P, Pascariello A, Pergher P, Poltnig W, Pušenjak M, Rampazzo R, Reszler C, Robinson C, Rollando A, Rosso M, Salvaro M, Schlamberger J, Scussel R, Siligardi M, Suette G, Valentar V, Varolo E, Vecellio C, Wagner K, Zadravec D, Zalavari P, Zessar H, Zolezzi G (2011): Water Management in a Changing Environment – Strategies against Water Scarcity in the Alps. Project outcomes and recommendations. University of Savoie, Chambery, France.
Lautenschlager, M and Keuler, K and Wunram, C and Keup-Thiel, E and Schubert, M and Will, A and Rockel, B and Boehm, U. Climate simulation with CLM, scenario A1B run no. 1, data stream 3: European region MPI-M/MaD, World Data Center for Climate, 10, 2009
Lehner, B.; Czisch, G.; Vassolo, S., 2005. The impact of global change on the potential of Europe: a model-based analysis. Energy Policy, 33(7): 839-855
Lionello, P., 2005. Extreme surges in the Gulf of Venice. Present and Future Climate, Venice and its lagoon, State of Knowledge. Fletcher, C. and Spencer, T. (eds.), Cambridge University Press, Cambridge, UK, pp. 59–65.
Margottini, C.: Cambiamenti climatici, dissesto idrogeologico e politiche di adattamento in Italia: un percorso tra passato, presente e futuro, Relazione presentata alla Conferenza Nazionale sui Cambiamenti Climatici, Roma, pg. 12-13, 2007
Massarutto, A., Water in climate change, 2011. http://www.cipra.org/en/publications/4807
Mercalli, L., Che tempo che farà: breve storia del clima con uno sguardo al futuro, 2009
OECD. Annual Report. 2007. Organisation for Economic Cooperation and Development.
Peeters, F., Livingstone, D. M., Goudsmit, G. H., Kipfer, R. and Forster, R. (2002) Modeling 50 years of historical temperature profiles in a large central European lake. Limnology and Oceanography 47, 186–197. doi:10.4319/lo.2002.47.1.0186.
Ranzi, R., Barontini, S., Grossi, G., Faggian, P., Kouwen, N., & Maran, S. (2009, August). Impact of climate change scenarios on water resources management in the Italian Alps. In *Proceedings of the 33rd IAHR Congress: Water Engineering for a Sustainable Environment, Vancouver, August* (pp. 9-14).
Smiraglia, C.; Morandi, G.; Diolaiuti, G. 2008. Clima e ghiacciai. L´evoluzione delle risorse glaciali in Lombardia. Consiglio Nazionale della Lombardia.
Tamburini, A., et al. "Slope Instabilities in High-Mountain Rock Walls. Recent Events on the Monte Rosa East Face (Macugnaga, NW Italy)." Landslide Science and Practice. Springer Berlin Heidelberg, 2013. 327-332.
Weingartner, R.; Viviroli, D. and Schädler, B., 2007. "Water resources in mountain regions: A methodological approach to assess the water balance in a highland–lowland system", Hydrological. Processes 21, pp. 578–585.
Valt M., A.Cagnati, A.Crepaz e G.Marigo. (2005). Neve sulle Alpi. Neve e Valanghe, 56, 24-31
Van Vliet, M. T. H., Yearsley, J. R., Franssen, W. H. P., Ludwig, F., Haddeland, I., Lettenmaier, D. P., and Kabat, P., 2012. Coupled daily streamflow and water temperature

modelling in large river basins, Hydrol. Earth Syst. Sci. Discuss., 9, 8335-8374
Viviroli D., Weingartner R., Messerli B (2003): Assessing the Hydrological Significance of the World's Mountains. Mountain Research and Development, 23: 32-40.
Viviroli D, Durr 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, Lopez-Moreno JI, Lorentz S, Schadler 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.
Zemp, M. and Haeberli, W. and Hoelzle, M. and Paul, F.. Alpine glaciers to disappear within decades? Geophysical Research Letters, 33,(13), 2006
Zottele, F., Toller, G. Eccel, E. Irri4web: crop water needs definition by webGIS. Italian Journal of Agrometeorology - 3/2010.