

# CLIMATE ADAPTATION AND NATURAL HAZARD MANAGEMENT IN THE ALPINE SPACE

FINAL REPORT

AUGUST 2011



 AdaptAlp

Adaptation to Climate Change in the Alpine Space



# **CLIMATE ADAPTATION AND NATURAL HAZARD MANAGEMENT IN THE ALPINE SPACE**

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This is a joint publication of the AdaptAlp project partnership. It encompasses the summary reports of the four thematic work packages of the project. The Final Report is one of 3 final project publications. More information about AdaptAlp products and findings can be found in the Technical Report and the Common Strategic Paper on the AdaptAlp Website.

#### *Acknowledgement*

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Bayerisches Staatsministerium für  
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## ABSTRACT

Climate change imposes extra stress on the social-ecological system of the European Alps. The rise of temperature as well as changes in precipitation measures have unforeseeable impacts on the intensity and frequency of natural hazards such as landslides and river floods. Therefore administrations and disaster managers call for a sound decision-basis including tools, data and good practice examples that may facilitate decision-making and the operationalization of climate adaptation measures.

The EU project AdaptAlp seeks to answer this demand by providing products, reports and recommendations for natural hazard and disaster management in the Alpine Space.

Different thematic topics were investigated throughout the 3-years collaboration. The working group “Water Regime” aimed at improving the knowledge base on climate change impacts on the Alpine water regime. A run-off data base for the Alpine Space was collected and harmonised, climate projections calculated for the Greater Alpine Region and impact analyses conducted for a number of Alpine river basins. The results show a continuation of the rise in temperature in all regions of the Alps. This will change the Alpine snow regime and lead to an increase in evapotranspiration. Furthermore, according to some projections, some model regions (e.g. Inn, Soča, Alpine Rhine) will see a further reduction of summer discharge and an increase in winter discharge in the future. Adaptation measures must not only take the whole river basin into account but must also base on local vulnerability analysis to the following possible impacts:

- general shift of water regime with discharge increase in winter, decrease in summer
- (near future) both increase and decrease of average total annual discharge possible
- (distant future) decrease in average summer and total annual discharge
- increase in flood frequency of small floods
- possible localised increases in erosion (river bed and soil)
- risk of water scarcity

All in all, planning and implementing protection or adaptation measures should follow a cyclical process taking into account new developments and findings continuously.

Beside a sound data base of hydro-climatological data the project aimed at providing clear guidance in the field of hazard mapping. Hazard mapping is an important element for risk management and is a valuable basis for spatial planning and further technical, financial and political decisions. Therefore the mandate of the working group “Hazard Mapping” was the identification of balanced adaptation measures to climate change by improving hazard mapping on a transnational basis, by harmonizing the technical terminology and by creating a basis for cross-sectoral hazard mapping procedures.

A multi-lingual glossary was elaborated to standardize the terminology for geological hazards across the Alpine Space including also English and Spanish terminology. Moreover, minimum requirements for the development and definition of all types of hazard and risk maps were defined and standards determined. Tools were developed that are able to enhance the mapping of endangered areas and for communication purposes. For example a semi-automatic tool for the identification of landslide susceptible areas and a multi-hazard and risk tool that produces factsheets to provide an overview of hazards and vulnerabilities in communities. A number of publication and handbooks for experts and practitioners (e.g. “Tracking of past events on fans and cones: dating techniques and applications”) were published.

Accurate data and information about climate impacts as well as the existence of hazard maps are essential for an integrated risk management. Only by coordinating and complementing responsibilities and actions optimum use of knowledge, experience and existing data can be made, so that the potential synergy of all the institutions involved can leverage the cost-effectiveness of risk appropriate measures. The working group “Risk Management and Risk Prevention” accomplished to integrate risk management, particularly risk dialogue, into the decision-making process to manage the challenging effects of climate change. Analyses and further development of existing methods and tools in all sectors of the risk cycle were performed. Furthermore, the cross-border dissemination of specialised knowledge through education and training of experts involved in risk management was strongly promoted (e.g. platform on [alp\\_exchange](#), handbooks for practitioners).

Risk communication and awareness raising at local level was also the main task of the working group “Pilot Activities”. In close collaboration with mayors and local stakeholders in the Großes Walsertal, Gasen/Haslau and Burgberg/Sonthofen workshops and campaigns were organised and networks established. Not only decision-makers but also children and students were involved in the communication and education process.

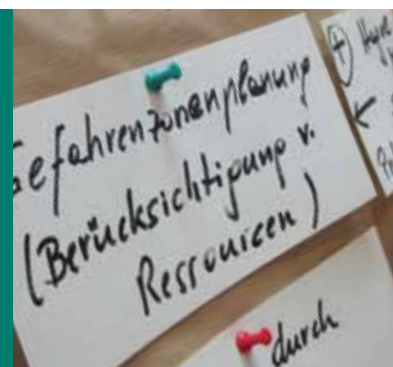
AdaptAlp has demonstrated that science, government and non-government organisations can successfully advance together, addressing climate changes occurring in the Alps and working to decrease the risks of its citizens for generations to come. The established networks and gained knowledge on natural hazards and climate change in the Alps will help to reduce risks and vulnerabilities.

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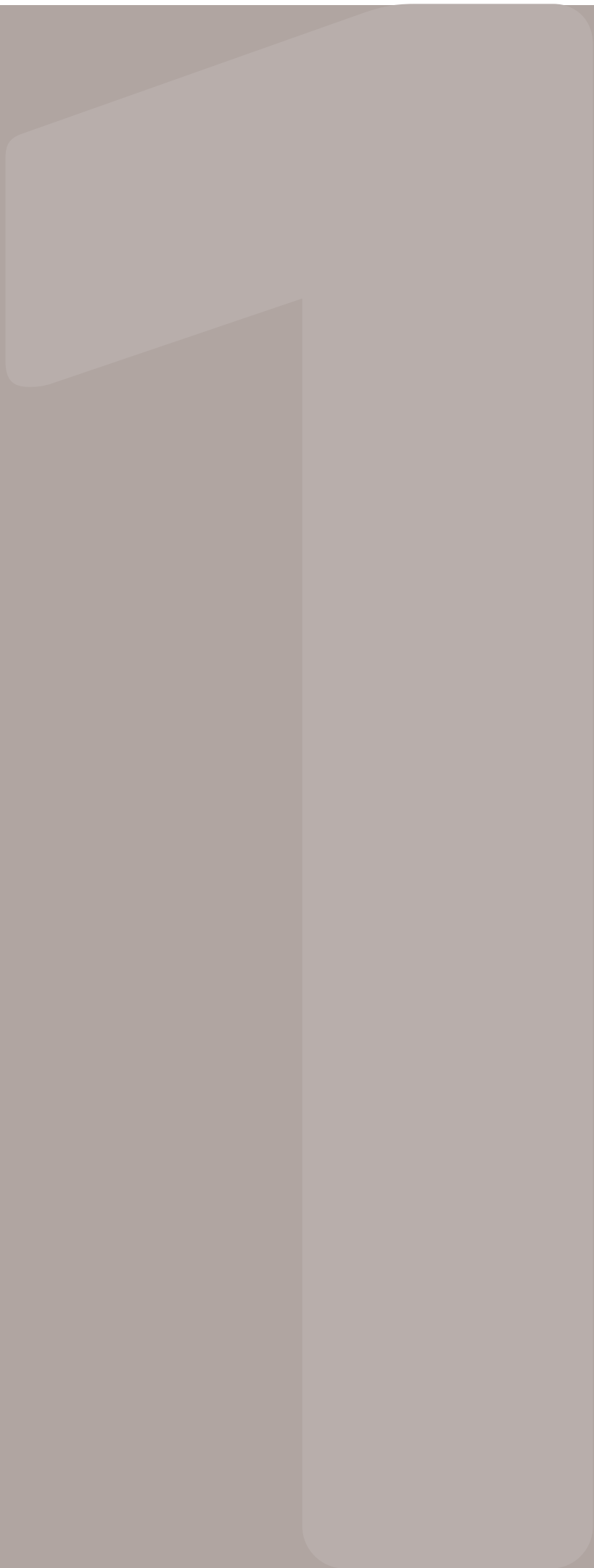
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## LIST OF ABBREVIATIONS

ASP .....	Alpine Space Programme
CC .....	Climate Change
CSP .....	Common Strategic Paper
COSMO-CLM .....	COSMO model in Climate Mode
GAR .....	Greater Alpine Region
GCM .....	Global Climate Model
GRDC .....	Global Runoff Data Centre
ICT .....	Information and Communication Technique
IPCC .....	Intergovernmental Panel on Climate Change
LS .....	Loading System
RCM .....	Regional Climate Model
RS .....	Response System
RUSLE .....	Revised Universal Soil Loss Equation
SRES .....	IPCC Special Report on [greenhouse gas] Emission Scenarios
WEPP .....	Water Erosion Prediction Project
WP .....	Work Package





# 1. | INTRODUCTION



## 1.1 | CLIMATE CHANGE AND NATURAL HAZARDS IN THE ALPS

Examples of increasing weather extremes and natural disasters have become so prevalent that they hardly bear repeating, but it may be useful to begin with a statistic. According to a study from the insurance company Munich Re, of a total of 825 catastrophes recorded during the period 1980-2006, almost all of the € 58 bn in economic losses are attributed to extreme weather.

In the Alps, adaptation to climate change calls for difficult decisions to be made by many interests. Given the potential cost of these decisions, government administrations must rely on current knowledge of climate scenarios and their expert interpretation to make the right choices.

While scientists believe that the climatic changes documented to date in the Alps will play a role in the occurrence of natural disasters, it is not yet possible to make a precise forecast from the available data. It is difficult to draw a complete picture of the effect climate change will have on natural hazard risks in the Alps.

In addition, the Alps have a range of physical characteristics that cause large variations in local weather conditions. This means that even more data is necessary before fully understanding the effect of climate change within each individual region.

Correctly interpreting the current climate change scenarios we do have is key to knowing what adaptation strategies to adopt. So what do we know about climate change in the Alps?

The temperature rose 1.5° C over the last 100 years, which is double the worldwide average. Furthermore, the average temperatures in the Alps rose far more rapidly than climate models predicted just ten years ago. It is highly probable that we will continue to see temperatures rise in the Alps faster than is being recorded elsewhere globally. Future precipitation is more challenging to anticipate. The average change is easier to talk about than the prediction of extremes. Agreement is generally high among climate models that in many regions of the Alps there will be a gradual increase in winter precipitation and a decrease in summer precipitation.

If and how these changes will impact the social and environmental system will vary from region to region. While some areas may be increasingly endangered by natural hazards such as floods and landslides, other regions may face problems related to water scarcity. Even if an exact prognosis of the Alps' climatic future is not yet possible, now is the time for long-term decisions to be made regarding the adaptation to natural hazards. A number of scientific and applied projects are currently dealing with climate change and its impacts on different sectors in the Alpine Space. They aim at filling knowledge gaps, providing considerable and sound information for adaptation strategies, and often act as kick-off for adaptation measures in regions or municipalities. This report is one of three publications by the AdaptAlp partnership giving a overview of key findings and major outcomes from the collaboration.

## 1.2 | INTEGRATED RISK MANAGEMENT

Integrated risk management of natural hazards is part of the holistic understanding of environmental risks that includes risk analysis; risk evaluation and reduction; and risk management. It incorporates all the measures that contribute to the reduction of damage caused by natural hazards. These include, for example, emergency management during disasters, the maintenance of protective structures, repair work, the maintenance of protective forests, and structural measures (see Figure 4.1). Integrated risk management is a task that must be carried out at transnational, national, regional and local administrative levels, and requires the interconnected and coordinated effort of many actors and institutions at each administrative level. All responsibilities and actions must be coordinated and must complement each other. The aim is to make optimum use of knowledge, experience and existing data so that the potential synergy of all the institutions involved can leverage the cost-effectiveness of risk-appropriate measures. Risk communication and risk dialogue are the preconditions for the efficient coordination of the activities of all the relevant actors. Without this, the advantages of integrated risk management cannot be obtained.

The catastrophic events of recent years have revealed weaknesses in risk management practice. We can see the wisdom in the maxim: "there are costs and risks to action, but greater long-terms costs to inaction". Today, the concept of 'vulnerability' is essential when understanding the risk of natural hazards. Assessing vulnerability in specific regions of the Alps is an integrated risk management process that has become commonplace. Putting the so-called 'integrated' approach into practice, however, is often held back by traditional ways of working. A high amount of flexibility is required as well as widespread education initiatives, collaboration across regions and sectors and a intensified dialogue between experts, affected people and decision-makers.



### 1.3 | PROJECT ADAPTALP

The project AdaptAlp contributes to a growing body of scientific research on the effect of climate change within the Alpine region and how our societies can adapt to the increasing risk of natural disasters. The intent was to deepen this knowledge so that decision-makers can craft coherent policies and programs based on current and accurate information. AdaptAlp is the result of three years of research of collaboration and exchange between sixteen partners from six Alpine Space countries. Between 2008 and 2011, more than 130 scientists, experts and government representatives from 24 institutions worked together to understand the complex issues of climate change and natural hazards in the Alpine region.

AdaptAlp focused on three areas:

- climate change and water regime analysis,
- natural hazard mapping,
- risk management and risk prevention.

Figure 1.1 delineates structure and official project partners. AdaptAlp was composed of seven Work Packages (WP). It was coordinated and led by the Bavarian State Ministry of the Environment and Public Health. Various observers and experts contributed with their expertise to the project. A list of project partners can be found in Annex 1.

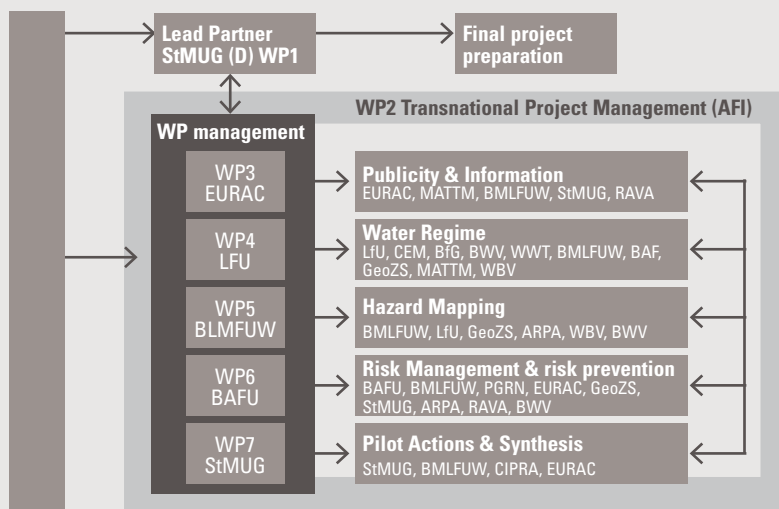


Figure 1.1: Project structure

The overall project goal was to generate a sound data basis for decision-makers and to put research into action. So, in addition to developing new methods and recommendations, the projects' government partners strongly collaborated with each other to devise pilot projects and networking initiatives that tested these ideas in designated pilot regions. More specially, the project partnership aimed at:

1. improving information on the potential impact of climate change at the regional level using state-of-the-art approaches (e.g. high resolution modelling),
2. evaluating and harmonising different methods of risk assessment, hazard mapping and risk management in the Alpine environment,
3. identifying good practice methods and transfer best practice experiences into adaptation measures in model regions, and finally
4. reducing risk by raising awareness among local stakeholders.

The results of the project serve as point of departure. They are designed to facilitate experts, decision-makers and local stakeholder to navigate the tricky terrain of Alpine natural hazards and climate change. A Technical Report, a Common Strategic Paper and this Final Report provide condensed and tailored information for the specific target groups.

### 1.4 | STRUCTURE AND AIM OF THE REPORT

This report bases on the summaries of the four thematic Work Packages “Water Regime”, “Hazard Mapping”, “Risk Management and Risk Prevention” and “Pilot Activities”. They are represented by Chapter 2–5. The aim of the WP summaries was to give a quick and informative insight in the broad range of Work Package findings and deliverables. Moreover, each WP provides a list of recommendations referring to its area of interest. For additional information please visit the project's website ([www.adaptalp.org](http://www.adaptalp.org) -> Technical Report). The target groups of the final report are disaster managers, experts from administrations and scientists.



## 2. | WATER REGIME

LEAD AUTHOR: JANE KORCK



## 2.1 | INTRODUCTION

### *Background*

The impact of climate change on water availability in the Alps was the subject of a report published in the first year of AdaptAlp by the European Environment Agency (EEA, 2009): „The Alps as ‚water towers‘ are extremely sensitive and vulnerable to various impacts including climate change. Due to global warming, changes in precipitation regimes, snow cover patterns and glacier storage will alter the water availability“. The same climatic changes that are likely to affect natural water availability may also have an impact on water related hazards such as floods and debris flows. For very small scale local phenomena (torrential floods, debris flows) or very rare events like river floods with long return periods, it is especially difficult to detect climate induced changes, as the uncertainties in both observations and simulations are particularly high. Nevertheless, a systematic approach to quantifying and, where possible, reducing these uncertainties, taking the widest possible range of methods and data into account, can provide a certain amount of robust information on which to base adaptation recommendations and strategies relating to both water-related hazards and water scarcity.

The same EEA report goes on to state that whilst “many lessons learnt from adaptation in the Alps are of a generic nature” [...] “key elements of successful strategies include tailoring measures to specific regional climate conditions”. The necessity for a local or regional perspective is a guiding principle of all the AdaptAlp studies relating to the water regime of the Alps. In this context, the importance of observed data cannot be overstated. This is also emphasised in the Alpine Convention’s 2nd Report on the State of the Alps „Water“ (Alpine Convention, 2009): “The natural basis for water resources management is the water balance, the temporal and spatial variation of the water resources. In order to provide a basis for decisions regarding water use, relevant monitoring of the hydrological cycle is absolutely essential. In this respect, water resources management also has a future-oriented role to play: it must react in good time to changes in the natural water availability - for example due to climate change - and make adjustments.”

### *Climate Change and Expected Impacts on Alpine River Basins*

Temperature and precipitation are the most important climatic drivers for the processes of the water cycle and changes in these variables are expected to have considerable impacts on the water regime. Over the past century, the global surface temperature has shown a relatively uniform temperature increase. Expressed as a global average, surface temperatures have increased by about 0.74°C over the past hundred years (between 1906 and 2005, IPCC, 2007). In the Alpine Space, average annual temperatures increased in the order of 2°C since 1890 with 1.2°C of the increase occurring in what could be described as a “temperature surge” after the 1970’s (Auer et al., 2007). Whilst many regions saw stronger warming in winter than in summer, winters and summers in the Alpine Space have warmed at comparably high rates.

The precipitation trends were more heterogeneous. Precipitation patterns depend on regional circulation patterns and local orography. Auer et al. (2005) analysed precipitation data for the 19th and 20th Centuries and detected opposite trends for different regions in the Alps: a wetting trend in the north-west of the Alps and a drying trend in the south east.

### *Climate Projections*

An analysis of a large number of climate projections carried out within AdaptAlp (see WP4 report “Climate Projections for the Greater Alpine Region”) showed an increase in the mean annual temperature in the GAR of up to 1.5°C in the period 2021-2050 and up to 3.5 °C in the period 2071-2100 compared with the period 1971-2000. The projected development of precipitation patterns in the Alps does not follow one single trend, though most of the models agree that precipitation totals in summer will decrease and that winter precipitation totals will increase. For the near future (2021-2050) compared with the recent past (1971-2000) annual precipitation totals show a slight increase over the year of +5% which holds for the winter, spring and autumn season, whilst the summer season sees a slight decrease of -5%. The decrease in summer precipitation totals is highest in the south-western part of the Alps, whilst the increase in winter precipitation totals is more or less evenly distributed over the Greater Alpine Region. For the distant future (2071-2100), compared with the period 1971-2000, some climate projections reveal a reduction in mean seasonal summer precipitation totals of up to -25%.

### *Objectives of the Work in the Work Package “Water Regime”*

Adaptation to climate change in the Alpine Space will demand compromises between different interests. It is vital that administrative bodies dealing with this sensitive subject are seen as reliable partners for all affected parties. Extreme caution is called for: Environment administration, in its role as advisor to local municipalities in the Alpine Space, cannot afford to use flawed climate data or interpret sound climate data incorrectly. In the water sector, the uncertainties are especially great. There is little observational data on extreme events and only a limited number of long time series of meteorological data or river discharge data are available. Also, climate modelling has significant limitations regarding rare and extreme events, so projections based on climate model data have to be interpreted in a responsible manner. As these matters are still the subject of



extensive scientific research, practitioners are called on to seek the advice of experts in the scientific community, whilst scientists need to take the special requirements of practitioners (e.g. data and guidance for the derivation of design events in a non-stationary climate) into account. The AdaptAlp Work Package “Water Regime” set itself the aim of providing solutions to these problems and meeting these challenges, both by exemplifying methods and by collecting, harmonising and analysing data for the whole of the Alpine Space. The specific Work Package objectives were:

- To assess local and large scale changes in Alpine rivers due to climate evolution over the last 40 years and longer
- To quantify the impact of projected climate changes on the water regime for different model regions in the Alpine Space as a basis for planning adaptation measures at the local and regional scale
- To provide methods and tools for hydrological modelling taking climate change into account and to provide guidance for stakeholders on their application in practice
- To improve the reliability of design events in pilot regions and to provide practitioners with generic guidance and specific methods for doing the same in other regions
- To provide those practitioners and decision makers who are planning adaptation measures and policies with up-to-date expert knowledge and specific recommendations concerning impacts of climate change on the water regime of Alpine rivers and hydrological hazards.

The provision of these tools, methods and data is expected to facilitate the harmonisation between countries and contribute to the implementation of EU Directives, e.g. the Floods Directive, another important WP4 objective.

#### *Primary Research Questions*

The following “knowledge gaps”, described in key publications on adaptation to climate change, especially in the water sector and in some cases with a special focus on the Alpine Space, were identified by the WP4 Partners as being particularly relevant to the work within AdaptAlp WP4:

IPCC – Fourth Assessment Report (AR4), Working Group II on Impacts, Adaptation and Vulnerability (2007)

- need for better understanding of climate change on local scale, especially precipitation change
- need for high quality observations and monitoring
- need for information based on impact studies using different scenarios at the regional and local scale

EEA report on climate change impacts in Europe (2008)

- need for consistent definition of indicators of climate change (e.g. for floods and droughts)
- need for impact analysis results based on a consistent set of global and regional models

EU Common Implementation Strategy for Water Framework Directive (2009) and policy paper (2006)

- need for reliable information on possible changes in flood risk and impacted areas

Alpine Convention Action Plan on Climate Change in the Alps (2009)

- need for harmonized procedures for defining risk areas for natural hazards (floods, landslides..)

Expert groups on water and climate change in Germany (DWA, 2010; LAWA, 2010)

- need to establish in which way which spatial scales and return periods are affected by climate change
- need to analyse to what degree climate change signals are within the range of uncertainty of existing design procedures and whether accounting for climate change would affect the overall levels of uncertainty, and consequently whether design procedures have to be adapted

#### *Definition of the Term “Water Regime”*

At the beginning of the AdaptAlp project, the partners in Work Package 4 agreed on the following working definition of the term “Water Regime”: The variability of the spatial and temporal patterns of the elements of the hydrological cycle – today and in the future. That includes: Interannual variability of the elements, frequency and extent of flooding, frequency and duration of drought, precipitation patterns (spatial distribution, extreme events), soil erosion trends, snowmelt and glacier dynamics.

## 2.2 | METHODS AND RESULTS

The studies carried out in AdaptAlp WP4 focus on the following five themes:

- *Detecting climate-induced trends in observed river discharge data*  
Activities: The “AdaptAlp Dataset” was created by collecting, reviewing and harmonizing long discharge time series from all over the Alpine Space. A set of hydrological indices was extracted in order to describe low, medium and high flows. Statistical trend analysis were performed at both the local and the regional scale in order to detect possible climate-induced changes in river regimes.
- *Assessing uncertainties in currently used methods for the determination of design events*  
Activities: Design events determined by methods such as flood frequency statistics and the design storm method were compared and evaluated, attempting to explain the discrepancies found.
- *A Climate Projection for the Greater Alpine Region with a new high resolution Regional Climate Model*  
Activities: A climate projection with a Regional Climate Model at very high resolution was developed using high horizontal resolution global model input to drive the regional non-hydrostatic climate model COSMO-CLM, with a horizontal resolution of approximately 14 and 8 km, to produce a more accurate picture of a possible future climate and in particular precipitation patterns in the Alpine Space.
- *Climate Projections for the Greater Alpine Region*  
Activities: An ensemble of regional climate projections was compiled based on the currently available results of 14 regional climate simulations provided by different research institutes in Europe using different couplings of global and regional climate models. The models were selected from an even larger ensemble of 20 simulations based on their bias characteristics.
- *Modelling possible impacts of climate change on a regional or local scale*  
Activities: Impact studies were carried out in several Alpine river basins that were selected as model regions. Climatologically, different parts of the Alpine Space can differ significantly and many local and regional climate change adaptation strategies will have to be based on studies at the river basin level.

The results of all these activities are documented in nine “WP4 Reports”. The following pages provide a short introduction to the WP4 reports as well as selected results from the underlying studies. Additional information is provided in the “AdaptAlp Technical Report”.

1. The AdaptAlp Dataset - Detecting climate-induced trends in observed river discharge data
2. Reassessing the reliability of design events in a changing climate
3. A Climate Projection for the Greater Alpine Region with a new high resolution Regional Climate Model
4. Climate Projections for the Greater Alpine Region
5. Water Regime in the Alpine Space: The River Inn Basin
6. Water Regime in the Alpine Space: The Alpine Rhine Basin
7. Water Regime in the Alpine Space: The Upper Soča River Basin
8. Water Regime in the Alpine Space: Soil Erosion Study in the Adda River Basin
9. Water Regime in the Alpine Space: Understanding Trends in Hydrologic Regimes in the Upper Durance (Rhône Basin)

### 2.2.1 | DETECTING CLIMATE-INDUCED TRENDS IN OBSERVED RIVER DISCHARGE DATA

In some cases, anthropogenic influences in river catchments have altered the local water regime to such an extent that a climate-related signal can no longer be detected with confidence. Other catchments have retained a water regime that is quite close to the natural state - sometimes despite the creation of water management infrastructure - making them suitable for detecting climate trends. In order to create a harmonised river discharge data set made up of such “suitable” time series from the whole of the Alpine Space, data fulfilling certain requirements (record length, measurement quality and absence of significant direct anthropogenic influence) was gathered by the AdaptAlp Partnership. In some cases partners were able to extend existing time series “backward” as far as 1900 by digitising historic paper hydrographs, providing a particularly valuable contribution to the dataset.

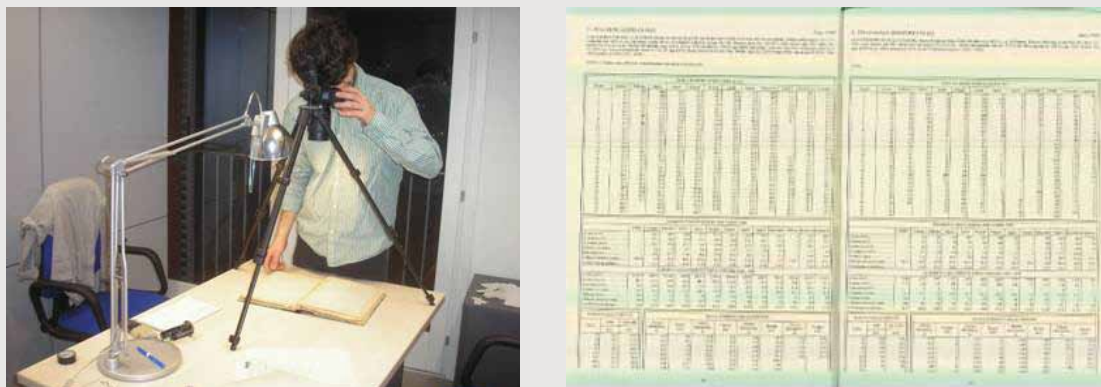


Figure 2.1: Digitising paper annals using a digital camera and optical character recognition (2010)

Following two review cycles, in which the local knowledge of the partners on anthropogenic influences played a crucial part, a final dataset with 177 time series was selected from the 342 candidate stations in the original raw dataset. The result is a harmonised cross-border database which provides long daily discharge time series (minimum record of 40 years) of good recording quality, representing undisturbed catchments over six countries of the Alpine Space. With the exception of some stations, removed to protect the rights of the data owners, the whole dataset will be made available on the GRDC database (grdc.bafg.de).

In order to assess local and large scale changes in Alpine rivers due to climate evolution over the last four decades and longer, hydrological indices that describe low, medium and high flows were analysed for the AdaptAlp Dataset. Statistical trend analyses were performed at both the local and the regional scale in order to detect changes in river regimes. The key findings of this large scale trend detection study for hydrological regimes - the first of its kind to cover the Greater Alpine Region (GAR) - relate to snow melt-related high flows and winter low flow.

The results show changes occurring for winter low flow conditions, which appear to be significantly less severe: The annual minimum is globally increasing (25 % of significant upward trends), and the annual volume deficit and drought duration are decreasing (25 % and 26 % of significant downward trends). Results for the spring snowmelt high flows show more consistency. A large number of stations present changes in the thaw seasonality: snowmelt start and centre occur earlier in the season (49 % and 29 % of significant downward trends), whereas the snowmelt sometimes ends later, leading to a longer duration of the snowmelt period (49 % of significant upward trends).

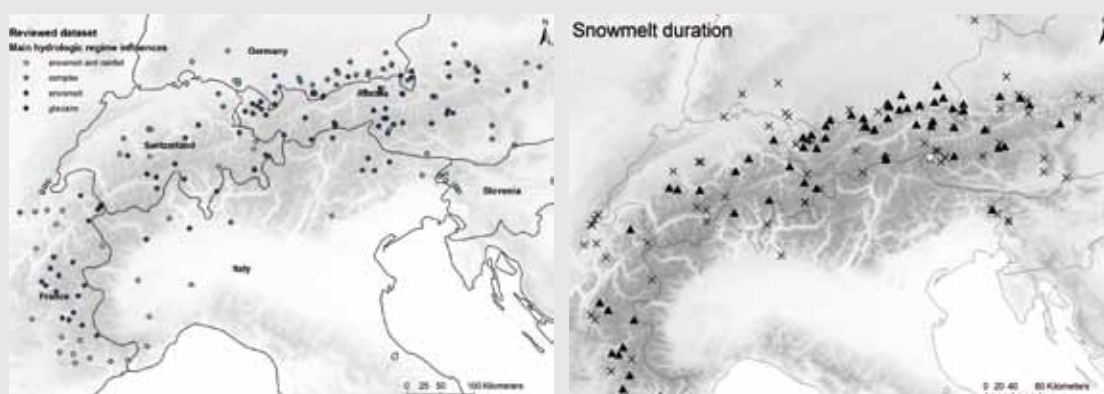


Figure 2.2: Left: Final AdaptAlp Dataset: 177 stations, most of which will be available on the GRDC database  
Right: Duration of snowmelt-related high flows: 49% of the stations with significant upward trend

Results concerning the intensity and volume of snowmelt high flow are not consistent on a large scale. However, regional analyses carried out at the scale of homogeneous hydro-climatic regions show a significant increase of the snowmelt-related flood intensity and volume for glacier-influenced rivers. Overall, the regional analyses suggest that trends affecting Alpine rivers strongly depend on the hydrologic regime of the river. For more details see the WP4 Report “The AdaptAlp Dataset - Detecting climate-induced trends in observed river discharge data”.

## 2.2.2 | REASSESSING THE RELIABILITY OF DESIGN EVENTS IN A CHANGING CLIMATE

The possible effects of climate change on design events were discussed in an expert meeting organised by the AdaptAlp Partnership in April 2009 in Vienna (see WP4 report “Reassessing the reliability of design events in a changing climate”). Generally, it was agreed that current uncertainties in the estimation of design events are still so high that it is hard to quantify the extent to which climate change affects the overall level of uncertainty. Hence, the aim of this study was to reduce the uncertainties in the estimation of design events. Design events were estimated with two methods, the design storm method and a stochastic approach with a continuous rainfall runoff model. The results were compared and analysed in order to identify reasons for discrepancies which are a common problem, not yet solved, with negative consequences in practical engineering applications. The case study was performed on ten pilot catchments (4-100km<sup>2</sup>) in Tyrol. The findings on a local scale were also included in a regional analysis.

The project consisted of different project parts:

- Estimation of design events based on stochastic simulations of the runoff processes with a continuous rainfall- runoff-model and stochastically generated precipitation series
- Estimation of design events with the design storm method using the event based Zemokost model
- Regional analysis of design events
- Hydrogeological assessment of the pilot catchments as input for the continuous and Zemokost model
- Sensitivity analysis regarding possible climate change impacts on the calculated design event

The results show some weaknesses in both the stochastic approach and the design storm method:

- Statistical extrapolation of often very short data records in Alpine catchments leads to high uncertainties in the estimated values. Stochastic simulation results showed that catchments with high storage capacity may exhibit a step change in the flood frequency curve, which causes the design event to be larger than the value estimated by flood frequency statistics. Hence, it is highly recommendable to take catchment characteristics into account when evaluating statistically estimated design events.
- Design storm methods are often based on maximized assumptions such as saturated conditions, very high values for design storms, high runoff coefficients, etc. The study showed that in Austria commonly applied design storm values are very high and therefore lower values for the estimation of the design events for catchments with a size like the pilot catchments of this project have to be used. Generally, it has to be taken into account that the return period of the estimated design event is only given based on the return period of the design storm, which can cause an underestimation of the actual return period.
- The results of a sensitivity analysis regarding possible climate change impacts found that a slight reduction of the flood discharge with a return period of 100 years is likely. Figure 3 (below) shows that whilst the most extreme summer floods may see a slight reduction in number, spring and summer floods can be expected to increase due to the climate induced shift in the water regime.
- The projected effect of climate change on flood events seems to be lower than the overall uncertainties of the methods for estimating design values. Hence, before assessing the impact of climate change on design events, uncertainties in the estimated values for present conditions have to be reduced. The use of both statistical and deterministic approaches can be very helpful in this context.

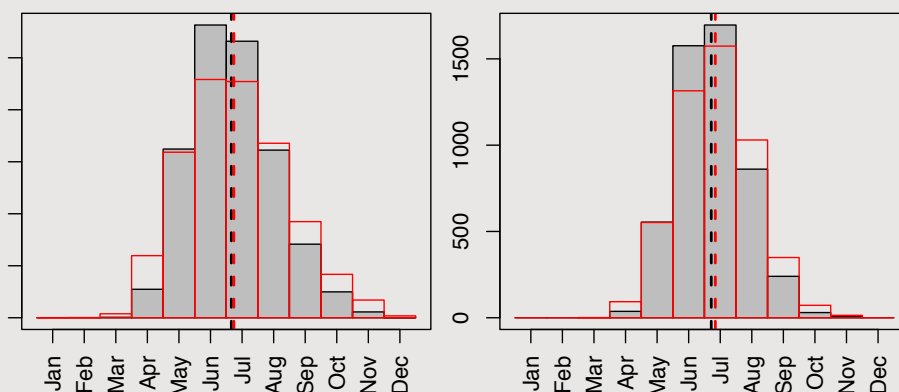


Figure 2.3:  
Northern tributaries to  
the Inn River in Tyrol:  
Simulated occurrence of  
annual maximum flood  
in a typical catchment –  
Present conditions in  
black and future scenario  
in red (Source: Blöschl et  
al., 2011)

These new findings help to explain and reduce uncertainties in the currently applied methods. Consequently, they also contribute to an improved flood risk management and the implementation of the EU Floods Directive. Furthermore, a reduction of the uncertainties in the applied methods helps to better estimate future impacts of climate change on design events (for further details see WP4 report “Reassessing the reliability of design events in a changing climate“ and the AdaptAlp technical report).



### 2.2.3 | A CLIMATE PROJECTION FOR THE GREATER ALPINE REGION WITH A NEW HIGH RESOLUTION REGIONAL CLIMATE MODEL

The AdaptAlp Partner MATTM contracted a scientific consortium, the Euro-Mediterranean Center for Climate Change (Centro Euro-Mediterraneo per i Cambiamenti Climatici – CMCC), to provide a new high horizontal resolution climate model data set, in particular at the regional scale, for the GAR. The first expected improvement is due to the use of the global climate models SINTEX-G and CMCC that provide the boundary conditions for the regional climate model simulations and have comparatively high horizontal resolutions (80-100 km) as well as a module that simulates the influence of the Mediterranean Sea on the European climate. The second is due to the “non-hydrostatic” regional climate model (COSMO-CLM), which was developed with the aim of achieving better simulations of convective events (e.g. storms). COSMO-CLM was used with a horizontal resolution of approximately 10 km, in order to produce the relevant climate variables at a high spatial scale and to allow a detailed description of the projected precipitation patterns in areas such as the GAR with its complex terrain. Work concentrated on the area defined by latitude 40-52 N and longitude 2-20 E. The greenhouse gas emission scenario A1B (SRES-A1B) was used to project the climate of the XXI century.

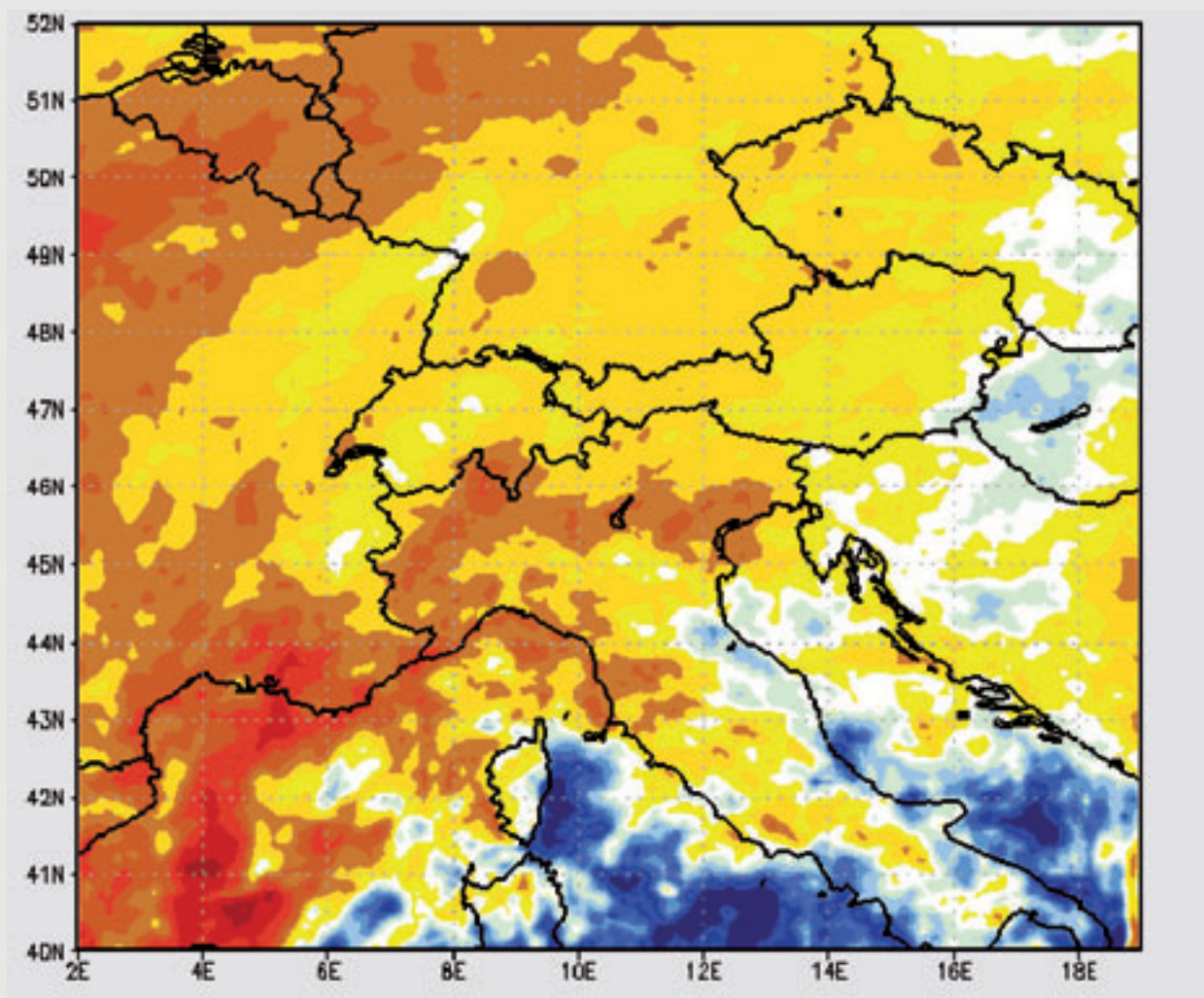


Figure 2.4: Results of high resolution regional climate modelling with COSMO-CLM - Projected changes [%] in average summer precipitation (June/July/August) for the period 2011-2035 compared with 1971-2000



The final outcomes of this work were the following new climate datasets for the Alpine Space containing the values of the main atmospheric variables (for detailed results see the WP4 report “A Climate Projection for the Greater Alpine Region with a new high resolution Regional Climate Model” and the AdaptAlp technical report):

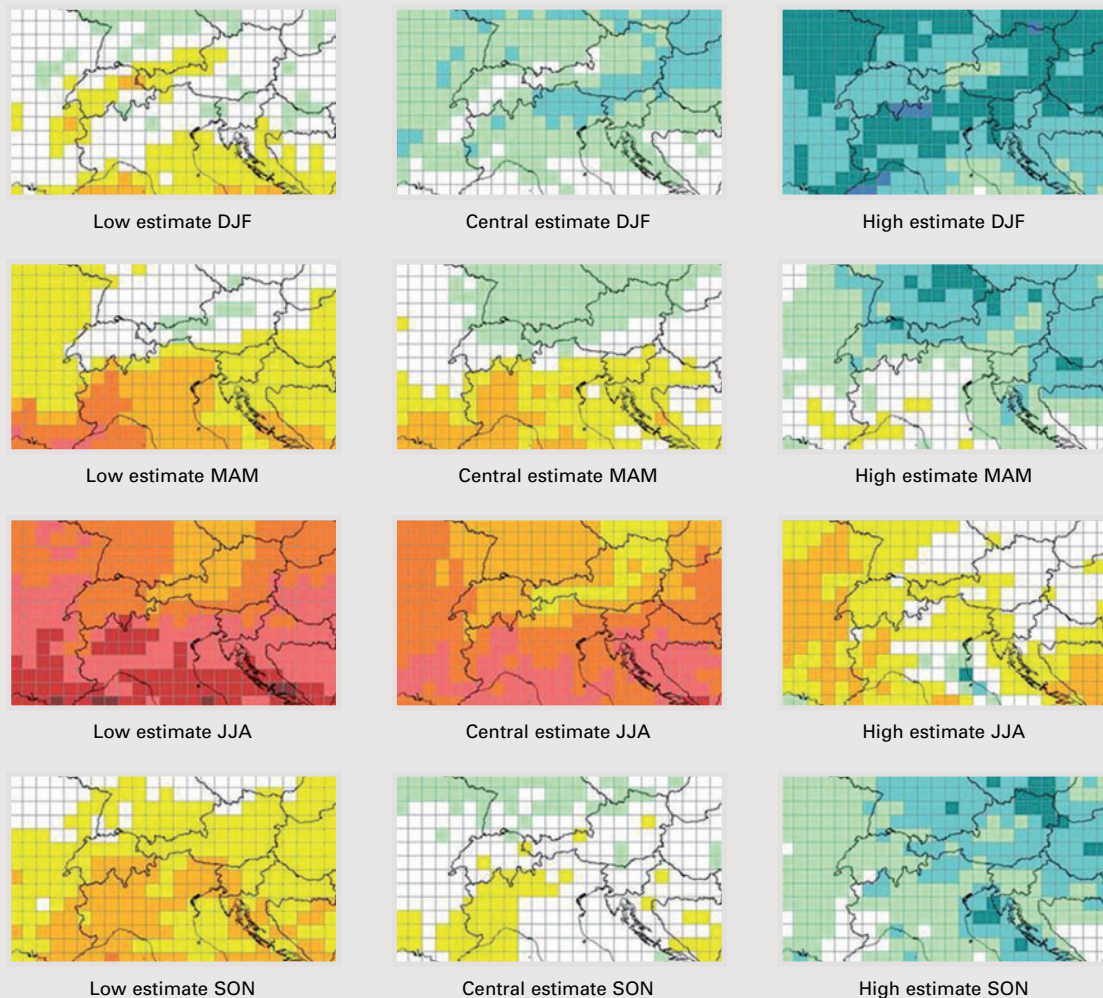
- XX century, spatial resolution 14 km, driving data by SINTEX-G
- XXI century, spatial resolution 14 km, driving data by SINTEX-G, A1B
- 1970-2000, spatial resolution 14 km, driving data by ERA-40
- 1965-2035 (2100), spatial resolution 8 km, driving data by CMCC-MED, A1B

## 2.2.4 | CLIMATE PROJECTIONS FOR THE GREATER ALPINE REGION

### *Visualisation of Climate Change Signals in Maps for the Alpine Space*

An ensemble of regional climate projections was compiled based on presently available model results of different dynamical RCMs from the EU-Project ENSEMBLES (van der Linden and Mitchell, 2009) and the German „CLM-Community“ (Hollweg et al., 2008). All projections are based on the global greenhouse gas emission scenario A1B (SRES-A1B). The climatic data covering the GAR were:

- processed to match an identical temporal and horizontal resolution
- evaluated and selected by comparison with each other as well as with an observation based data set
- grouped into a well defined ensemble of 14 climate projections (couplings of four global and eight regional climate models)
- analysed for regional climate change signals in the GAR.



*Figure 2.5: Change in seasonal average precipitation in the Alpine Space [%] for the period 2071-2100 compared to 1971-2000. Low, central, and high estimates were calculated as the 10th, 50th and 90th percentile. Model data of 14 GCM-RCM combinations were retrieved from the resources mentioned in the text and aggregated to common 50 km x 50 km raster data in Lambert conform conic projection. DJF (December/January/February), MAM (March/April/May), JJA (June/July/ August), SON (September/October/ November).  
Graphic: BfG (for details see WP4 report “Climate Projections for the Greater Alpine Region”)*

The expected changes for the near (2021-2050) and for the distant future (2071-2100) are visualised in maps showing deviations from the 20th century climate (1971-2000) as simulated by an ensemble of 14 regional climate models. The ensemble makes it possible to display the uncertainty range associated with the change information. Figure 5 gives an example for the range of future precipitation changes per meteorological season and per 50 km grid cell. The central estimate corresponds to the median of the ensemble. The low and high estimates state that there are only very few simulations showing lower or higher change signals, respectively. If the differences between the estimates were small, the uncertainty could be considered relatively low. For the precipitation signals given here, the uncertainty is generally higher than that of the temperature signals.



Further maps and detailed information on the processing steps as well as further statistics and evaluations for different meteorological sectors of the GAR are available in the WP4 report “Climate Projections for the Greater Alpine Region” and the supplementing technical report.

#### *Ensemble Climate Projections - Input for Regional Impact Studies*

For regional impact studies, specific sub samples covering the climate of the 20th century (1951-2000) and the future climate forced by the A1B-Emission scenario (2001-2100) are selected from a larger regional climate model ensemble including runs not originating from the ENSEMBLES project. The selection was done with respect to the specific question of the impact study.

Before using the individual regional climate model runs for studies with a focus on natural hazards, especially for hydrological impact analysis, the application of bias correction techniques is recommended (see ClimChAlp, 2008), Rheinblick, 2010). Climatic data sets based on observations are used as the reference for bias correction. However, selecting a suitable statistical correction technique requires careful testing as it is also a potential source of systematic errors, especially in the light of weaknesses of available observation data in the Alpine Space. Impact studies in several pilot regions used different techniques: A “Linear Scaling” method, a “Quantile-Quantile-Mapping” method and the so-called “Delta Change” method, which “avoids” rather than corrects the bias, were tested and compared. The methods were applied to daily and in some cases monthly precipitation as well as air temperature data and other hydrometeorological variables. The following tools were developed during this study:

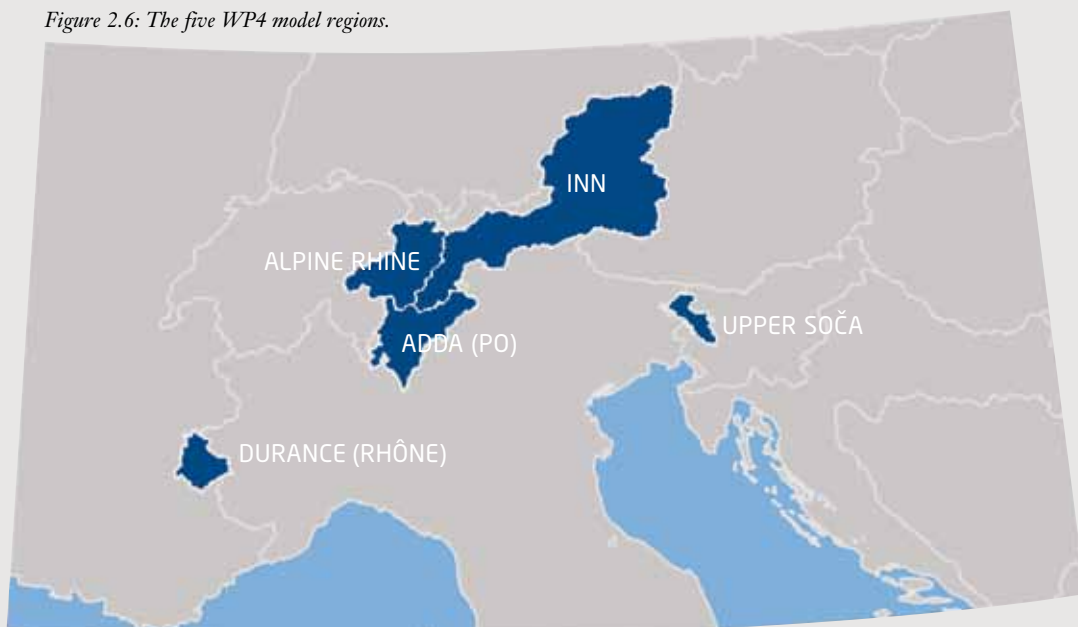
- Computer routine for bias correction of daily precipitation data by Quantile-Quantile-Mapping.
- Computer routines and interpolation methods for regionalising meteorological variables from large to smaller grid sizes, e.g. 50 km x 50 km to 5 km x 5 km.

A description of the validation results is available in the technical report. The application and hydrological validation of the tools for bias correction and the delta change method are reported separately in the regional reports for the rivers Alpine Rhine, Inn and Soča and the corresponding technical reports.

## 2.2.5 | MODELLING POSSIBLE IMPACTS OF CLIMATE CHANGE ON A REGIONAL OR LOCAL SCALE

Several activities in AdaptAlp WP4 focus on the assessment of climate induced changes in the water regime of river basins in the Alpine Space and consequences for hydrological hazards. As different hydrological phenomena such as river floods, flash floods, debris flow or drought are triggered by processes at very different scales, a wide range of temporal and spatial scales are covered by the different studies. The “Regional Reports” for the Inn River basin, the Alpine Rhine River basin, the Upper Soča River basin, the Adda River basin (part of the Po River Basin), and the Durance River basin (part of the Rhône River Basin) plus a whole range of background documents are available on the AdaptAlp website ([www.adaptalp.org](http://www.adaptalp.org)).

Figure 2.6: The five WP4 model regions.





## INN - WATER REGIME IN THE ALPINE SPACE: THE INN RIVER BASIN

The focus of this report is on quantifying the effects of climate change on the discharge of the Inn River basin including the uncertainties associated with this information and on applying a wide range of new methods and data.

### GEOGRAPHY

Countries: Switzerland, Austria, Germany, (Italy)  
 Drainage area: approx. 26 000 km<sup>2</sup>  
 Altitude: 290 m – 4000 m (approx.) above sea level

### CLIMATE

Average temperature (1971-2000): 6.3 °C\*  
 Average rainfall (1971-2000): 1400 mm\*\*  
 Mean actual evapotranspiration: 500 mm\*\*

### HYDROLOGY

River length: 517 km  
 Name of exit gauge: Passau-Ingling (D)  
 Mean daily discharge exit gauge: 739 m<sup>3</sup>/s\*\*\*



*The River Inn flows into the Danube in the city of Passau (Photo: Bavarian State Ministry of the Environment and Public Health)*

\* Climate station mean

\*\* According to long term water balance simulation for the study area with the hydrological model WaSiM-ETH for 1971-2000

\*\*\* Based on observed values for the period 1920-2006

The regional report on the Inn River basin comprises results from several hydrological studies and one soil erosion study with a regional focus on the Inn River and its tributaries. Discharge scenarios and soil erosion simulations are evaluated for the whole of the Inn River basin, as are hydrological projections for selected sub-catchments. Data and methods were provided, tested and compared by several AdaptAlp partners.

A central aim was to assess the uncertainties resulting from the choice of SRES, GCM, RCM, methods for further downscaling and bias correction and the impact model itself. More than 40 variations of the model chain SRES > GCM > RCM > Downscaling and Bias Correction > Impact Model were implemented for the Inn River basin. Both regional dynamic climate models driven by global climate models, for example the model runs available from the EU-ENSEMBLES project (ENSEMBLES Summary Report van der Linden and Mitchell, 2009), and statistical climate models like the German model “WETTREG” (Spekat et al., 2007) were included in the studies. Another important aspect was the choice of impact model.

As shown in Table 2.1, different hydrological models and model variations were used for different focus regions and the results compared (see WP4 Regional Report “Water Regime in the Alpine Space: The Inn River Basin”).

IMPACT MODEL	FOCUS REGION	FOCUS THEME	ADAPTALP PARTNER
COSERO	Inn and sub basins	Climate & hydrological change	BfG
PREVAH-WSL	Engadin (Swiss Inn)	Climate & hydrological change Snow & glacier scenarios	BAFU
WaSiM-ETH	Inn and sub basins	Climate & hydrological change (also extremes) Climate reference (regionalisation methods)	LfU
RUSLE	Alpine part of the Inn River basin	Soil erosion trends in a changing climate	MATTM

Table 2.1: Applied models and study focus for the Inn River basin

The regional climate change signals for the Inn River basin differ slightly from those for the whole GAR. The projected increase in annual mean temperature for the Inn River basin is in the order of 1 - 2°C by 2050 and up to 4°C by 2100, with highest temperature increases occurring in winter. The majority of the projections included in the presented studies show no significant change in overall precipitation amounts for the near future, though most models showed shifts in seasonal precipitation patterns (reductions in summer, increases in winter). Towards the end of the century some models showed significant reductions in summer precipitation. Impact modelling showed that the projected climatic changes would affect the water regime of the Inn River basin in several ways:

- Projections for mean annual discharge in the Inn basin show a clear seasonal shift both for the near future (until 2050) and towards the end of the century, with an increase in the usually much lower winter discharge and a decrease in the usually high summer discharge levels. This would mean a shift towards a more rainfall influenced regime, though snowmelt processes will continue to play an important role.
- Concerning hydrological drought occurrence and severity, the projected regime shift can generally be seen as having a mitigating effect. Nevertheless, the impact of rising temperatures and decreasing precipitation could have highly negative consequences at the local scale. To identify potentially critical areas and
- Some projections show significant increases in average high flow discharge for winter months. However, an assessment of possible changes in flood risk at the local scale is not possible based on the tools and methods presented here. The “model chain” is less reliable for extreme events than for the average water balance and has its greatest weaknesses regarding extreme events at the local scale.

A soil erosion study using an empirical model was carried out for the Inn River basin. The results, which are based on a new high resolution Regional Climate projection for the GAR produced within AdaptAlp, showed some localised decreases in erosivity (see WP4 Regional Reports “A Climate Projection for the Greater Alpine Region with a new high resolution Regional Climate Model” and “Water Regime in the Alpine Space: The Inn River Basin”).



## ALPINE RHINE- WATER REGIME IN THE ALPINE SPACE: THE ALPINE RHINE RIVER BASIN

The special focus of this report is on the simulation of flooding and low water conditions using downscaled and bias-corrected data from regional climate model runs combined with medium and high resolution water balance models for selected tributaries and the whole Alpine Rhine River basin.

### GEOGRAPHY

Countries: Switzerland, Germany  
Catchment area 6.120 km<sup>2</sup>  
Altitude: 400 m –1800 m above sea level  
Glacier cover: 1.4%

### CLIMATE

Average rainfall 1400 mm (1971-2000)  
Average temperature 2.3 °C (1971-2000)

### HYDROLOGY

River length: 170 km  
Name of exit gauge: Gauge Dipoldsau  
Mean daily discharge: 231 m<sup>3</sup>/s (1984-2008)  
Mean annual flood: 1340 m<sup>3</sup>/s (1919-2009)



*The Alpine Rhine near Domat-Ems (Photo: BAFU)*

For the study region of the Alpine Rhine, runoff projections as a response to regional climate changes induced by anthropogenic greenhouse gas forcing were generated and examined with regard to changes in statistical hydrological key measures. Both the regional and the local scale was considered taking into account the whole Alpine Rhine basin and selected meso scale sub-catchments (~150 km<sup>2</sup>). A downscaled and bias corrected ensemble of regional climate projections, forced by the emission scenario A1B, provided the input for hydrological modelling with the water balance and rainfall-runoff models PREVAH and HBV SMHI. Indicators for changes in the runoff regime with regard to mean discharge as well as indicators characterising low water and high flow (floods) were analysed (see technical reports). The ensemble of hydrological runoff simulations, the selection of hydrologically relevant impact indicators and the hydrological modelling procedures developed for generating these data sets all aim to provide a sound basis and guidance for performing detailed vulnerability studies, analyses of adaptation capacity and studies with regard to adaptation options influenced by hydrological pressures.

The calculated hydrological runoff ensemble (82 members) for the Alpine Rhine shows the following developments in the future compared to 1961-1990 (1979-2008):

Mean flow:

- Most of the models agree that the yearly mean runoff will only change marginally in the near future between +5% and -5%. In the distant future a tendency towards less water availability becomes clearer. Most of the model runs indicate runoff reductions of -5% to -10% at the end of the 21st century.

Low flow:

- The tendencies described for the annual course of monthly mean runoff can be seen in statistics characterising the monthly distribution of low water, too. Due to the fact that the low water periods of Alpine water regimes are in the months of the hydrological winter half year, the low flow indicator indicates an increase of runoff during low water phases of +5% to +30% in the near future and +10% to +50% in the distant future.

High flow:

- Most of the model runs indicate that high flow will be lowered in the summer months and will increase in the months of the hydrological winter half year.
- Most of the hydrological models driven with the bias corrected output of the dynamical regional climate models agree that there is no evidence that high flow conditions in the winter months will exceed the peak flows of the summer floods of present climate and hydrological conditions. Only two out of the of nine runs indicate an increase of high flow in the near and in the distant future by ~ +15 %.

It has to be noted that the reliability of the modelling results generally decreases from estimates for mean flows down to estimates for low flows and further on to high flows. Especially the assessment of future developments of severe and extreme floods needs more detailed analysis (see WP4 regional report on the Alpine Rhine Basin).



## UPPER SOČA - WATER REGIME IN THE ALPINE SPACE: THE UPPER SOČA RIVER BASIN

The special focus of this report is on the simulation of groundwater recharge and groundwater availability using bias corrected regional climate model data combined with a hydrological model for the Upper Soča River basin.

### GEOGRAPHY

Countries: Slovenia, (Italy)  
Size: 1 300 km<sup>2</sup>  
Altitude highest point above sea level: 2 864 m  
Altitude lowest point above sea level: 130 m

### CLIMATE

Average rainfall: 2 500 mm/year (1961–1990)  
Average temperature: 7 °C (1961–1990)

### HYDROLOGY

River length: 70 km  
Name of exit gauge: HPP Doblar  
Drainage area : 1 300 km<sup>2</sup>  
Average discharge: 78 m<sup>3</sup>/s (1980 – 1992)



*River Soča (Photo: Simon Mozeti)*

For the Upper Soča River basin, an impact assessment of projected climate change on the hydrological cycle was performed. It was based on a combination of climate model data and hydrological modelling. As meteorological input for the hydrological projections, a regional climate model simulation from the EU-ENSEMBLES project (ENSEMBLES Summary Report van der Linden and Mitchell, 2009) was downscaled and bias corrected for local use (see WP4 report “Climate Projections for the Greater Alpine Region”). Hydrological modelling was performed with the distributed hydrological model MIKE SHE/ MIKE 11. Quantification of possible impacts was achieved by comparing results of the hydrological modelling for control (1965–2005) and different scenario periods (2011–2040, 2041–2070, 2071–2100). Results of the modelling were also implemented in AdaptAlp Work Package 5 “Hazard Mapping” in a study on water-related hazards (see Technical Report Janža, 2011).



The climate projection applied in this study shows an increase of the average temperature (+0.9 °C, +2.3 °C, +3.8 °C) and precipitation amount (+6 %, +4 %, +2 %) in all scenario periods (see Technical Report Janža, 2010). More significant are changes of the temporal pattern of mean monthly values (up to +5.1 °C and +/-45 %) which result in warmer and wetter winters and hotter and drier summers in the scenario periods. The projected rise in temperature is reflected in the increase of actual evapotranspiration (+5 %, +11 %, +17 %) and reduction of snow amount (-1 %, -65 %, -89 %). Changes in temporal patterns (+60 %, -40 %) and average discharges (+6 %, +6 %, +1 %) follow the trends of meteorological variables. The frequency of simulated high water events increases only in the near future scenario periods (2011–2040), while the occurrence of droughts is higher in all scenario periods. Together with a projected extended period of decreased discharges that is shifted towards late autumn, droughts are identified as one of the most important issues in future water management. The analysis of projected groundwater recharge and water use (based on water permits) allowed the identification of water resources most vulnerable to climate change in the model area (see WP4 regional report on the Upper Soča River Basin and Technical Report Meglič, 2011b).

A soil erosion study using both the physically based WEPP model and the empirical model RUSLE was carried out for the Upper Soča River basin. The results, which are based on the climate conditions projected for the period up to 2035 by the transient 8 km “AdaptAlp” COSMO-CLM run (see WP4 Report “A Climate Projection for the Greater Alpine Region with a new high resolution Regional Climate Model” and AdaptAlp technical report), showed an overall tendency towards decreases in soil erosion with localised increases in the eastern parts of the study area that could prove significant. Moreover, a small scale application of the WEPP model shows quite wide variations in soil erosion rates within the same area (less than 10 km<sup>2</sup>), locally with some noticeable erosion risk increase.



## ADD (PO) - WATER REGIME IN THE ALPINE SPACE: SOIL EROSION STUDY IN THE ADDA RIVER BASIN

The special focus of this report is on modelling soil erosion in the Southern Alps and assessing potential changes in soil erosion under different climatic conditions.

### GEOGRAPHY

Countries: Italy, (Switzerland)  
Altitude highest point: 4049 m  
Altitude lowest point: 125 m

### CLIMATE

Average rainfall: 750–2400 mm/year (1961–1990)  
Average temperature (max/min): 12.3/–9 °C (1961–1990)

### HYDROLOGY

River length: 313 km  
Exit point: below the Brembo-Adda junction  
Drainage area approx: 5170.5 km<sup>2</sup>  
Average discharge: 177 m<sup>3</sup>/s (1961–1990)



*The Adda River (brown with sediment eroded from its upper basin) entering Lake Como  
(Photo: Michele d'Amico).*

Soil erosion is regarded as the most widespread kind of soil degradation, possibly becoming a concern from a physical, chemical and biological point of view. Many human activities (infrastructure, agriculture, forest management) disturb land surfaces, resulting in an increase in erosion. Changes in the rainfall regimes, caused by climate change, can also affect soil erosion rates. Two appropriate soil erosion models were chosen for an analysis of erosion processes in Alpine regions at two different application scales: the WEPP model (physically based) was selected for the erosion estimation in a small catchment system in the Adda River basin (less than 10 km<sup>2</sup>), while RUSLE (empirical model) was applied at the regional scale to the whole Adda River basin<sup>1</sup>.

<sup>1</sup> RUSLE was also applied to the river basins Inn and So a, WEPP was also applied to a small catchment within So a basin; the results are reported in the technical report and the respective regional reports.

The main objectives are summarised as follows:

- Testing the ability of the models to estimate the surface erosion processes for large basins and small sub-catchments;
- Application of the models for present day conditions and climate change scenarios;
- Analysis of results and trends and evaluation of the impact of climate change on soil erosion rates;
- Suggestions and recommendation on adaptation measures in the case of increased risk.

The meteorological input for the models was based on the transient 8 km “AdaptAlp” COSMOCLM run which projects climate conditions for the period up to 2035 (see WP4 report “A Climate Projection for the Greater Alpine Region with a new high resolution Regional Climate Model”). Together with all other parameters, the reduced rainfall erosivity leads to an overall decrease in soil erosion in the Adda River basin (see WP4 Regional Report “Water Regime in the Alpine Space: Soil Erosion Study in the Adda River Basin”).

The comparison of the modelled present-day situation with the future scenario suggests that an increase in the rainfall erosivity index will be observed outside the Alpine chain and in the humid pre-Alpine areas, with the exception of a small area in the central Alps. Thus, the increase in soil erosion may be less relevant to high altitude areas, which are by far the most vulnerable because of soil properties and vegetation cover. It is to be remarked that the considered models are not yet able to take modifications in land cover and management into account. Since such modifications are usually connected to human activities (urbanization, road construction, animal grazing, forest logging and fires), the possible impact of climate change on human activities must be taken into account, from an ecological, social and economical point of view too, thus possibly leading to a truly integrated approach to the assessment of erosion risk. Such additional factors could prove highly relevant for the assessment of superficial soil erosion in connection with climate change, and should be taken into account in future studies.



## DURANCE (RHÔNE) - UNDERSTANDING TRENDS IN HYDROLOGIC REGIMES IN THE UPPER DURANCE (RHÔNE BASIN)

The special focus of this report is on modelling soil erosion in the Southern Alps and assessing potential changes in soil erosion under different climatic conditions.

This study was carried out in the context of the statistical trend analysis performed on the basis of the AdaptAlp Dataset (see WP4 report “Detecting climate-induced trends in observed river discharge data” for more details). The analysis of the series from this dataset revealed significant trends affecting certain aspects of Alpine hydrologic regimes e.g. decreasing severity of winter droughts, earliness of snowmelt-related flows, increasing runoff for glacier regimes. The aim of this study is to evaluate whether these trends correspond to the expected response of the catchments to the evolution of climate forcings for selected sub-catchments of the Durance. The strategy used to achieve this objective is to simulate the river discharge response to observed climate forcings (retrieved from the SAFRAN database) using the hydrologic model SIM (SAFRAN-ISBA-MODCOU), and to compare the trends detected in observed and simulated discharge.

Results from this analysis reveal a lack of consistency between trends affecting observed and simulated discharge. More precisely, significant trends are detected in observed discharge for regime and high flow variables (decreasing annual mean discharge, increasing precocity and duration of the snowmelt period, decreasing volume of snowmelt-related flows). However, these trends are not significant for the simulated discharge. Conversely, a significant trend toward an earlier end of the drought period is detected on simulated discharge, but this trend is not significant for observed discharge.



Figure 2.7: Location of seven hydrologic stations in the Upper Durance and picture of a typical torrential stretch

This lack of consistency suggests that non-climatic factors might play a role in the evolution of observed discharge. However, this conclusion should be regarded with some caution for at least two reasons: (i) Non-homogeneities in the forcing data may dampen or exacerbate “genuine” trends caused by the evolution of forcings; (ii) although the standard Nash-Sutcliffe efficiency measure suggests an overall good performance of the hydrologic model, further analyses revealed stronger deficiencies for specific aspects of the hydrologic regimes (e.g. high/low flow).

Although the results of this study are somehow inconclusive, they illustrate the difficulty of disentangling the roles of various possible causes of change in hydrologic series.

## 2.3 | CONCLUSION

A whole range of conclusions can be drawn from the work carried out within WP4. In some cases, these are supported by several or even all of the studies contributing to the WP4 outputs, whilst in other cases they are specific to one activity. An analysis of the main findings in the WP4 studies showed that the final conclusions focus on three themes:

- Projected developments in the Alpine water regime
- Planning adaptation measures and strategies
- Current knowledge gaps

In the interest of conciseness, the WP4 conclusions in each category are presented below as bullet points, with the WP4 reports on which they are based listed directly below.

### 2.3.1 | EXPECTED DEVELOPMENTS IN THE ALPINE WATER REGIME

Observations over the last 40 years show less severe winter drought and longer spring high flow duration, mainly due to snowmelt starting earlier. Also glacier fed rivers have seen an increase in summer discharge.

*WP4 Reports:*

- “The AdaptAlp Dataset – Detecting climate-induced trends in observed river discharge data”

Many reports suggest that we will see a continuation of the rise in temperature in all regions of the Alps. This will change the Alpine snow regime and lead to an increase in evapotranspiration.

*WP4 Reports:*

- “Climate Projections for the Greater Alpine Region”
- “INN - Water Regime Study in the Inn Basin”
- “ALPINE RHINE - Water Regime Study in the Alpine Rhine Basin”
- “UPPER SOČA - Water Regime Study in the Upper Soča Basin”
- “A Climate Projection for the Greater Alpine Region with a new high resolution Regional Climate Model”

Precipitation change remains difficult to assess. Agreement is generally high among climate models that summer precipitation will decrease, especially towards the end of the 21st century.

*WP4 Reports:*

- “Climate Projections for the Greater Alpine Region”
- “INN - Water Regime Study in the Inn Basin”
- “ALPINE RHINE – Water Regime Study in the Alpine Rhine Basin”

According to some projections, some model regions (e.g. Inn, Soča, Alpine Rhine) will see a further reduction of summer discharge and an increase in winter discharge in the future.

*WP4 Reports:*

- “INN - Water Regime Study in the Inn Basin”
- “ALPINE RHINE – Water Regime Study in the Alpine Rhine Basin”
- “UPPER SOČA – Water Regime Study in the Upper Soča Basin”

None of the studies detect any indication that climate change will significantly affect flood peak discharge levels for rare flood events (e.g. return period 100 years) – this does not mean there will be no changes, it means we currently don't know.

*WP4 Reports:*

- “Reassessing the reliability of design events in a changing climate”
- “INN - Water Regime Study in the Inn Basin”
- “ALPINE RHINE – Water Regime Study in the Alpine Rhine Basin”

## 2.3.2 | PLANNING ADAPTATION MEASURES AND STRATEGIES

Adaptation measures and strategies must take into account the uncertainty of the climate change estimates, including the possibility that the future climate could move outside the today's estimated range. Results for large areas averaged over time are considerably more reliable.

### *WP4 Reports:*

- "Climate Projections for the Greater Alpine Region"
- "INN - Water Regime Study in the Inn Basin"
- "ALPINE RHINE - Water Regime Study in the Alpine Rhine Basin"

Adaptation policies should take the whole river basin into account, as alpine sub-basins and low land areas could react differently to climate change.

### *WP4 Reports:*

- "Reassessing the reliability of design events in a changing climate"
- "INN - Water Regime Study in the Inn Basin"

Adaptation measures and strategies must be based on local vulnerability to natural hazards in general and to observed and projected regional climate change impacts. Projections for the model regions showed one or more of the following impacts:

- general shift of water regime with discharge increase in winter, decrease in summer
- (near future) both increase and decrease of average total annual discharge possible
- (distant future) decrease in average summer and total annual discharge
- increase in flood frequency of small floods
- possible localised increases in erosion (river bed and soil)
- risk of water scarcity

The implementation of adaptation measures based on a local analysis of vulnerability to these possible impacts is recommended, taking the effects of local human activity into account.

### *WP4 Reports:*

- "Reassessing the reliability of design events in a changing climate"
- "INN - Water Regime Study in the Inn Basin"
- "ALPINE RHINE - Water Regime Study in the Alpine Rhine Basin"
- "UPPER SOČA - Water Regime Study in the Upper Soča Basin"
- "ADDA (PO) - Soil Erosion Study in the Adda Basin"

Where observations and simulations regarding climate change are inconclusive, sensitivity analysis at the local level can provide a basis for planning adaptation measures.

### *WP4 Reports:*

- "ALPINE RHINE - Water Regime Study in the Alpine Rhine Basin"
- "INN - Water Regime Study in the Inn Basin"

Ideally, indicators both for climate change impacts and for the effectiveness of adaptation measures should be defined and determined consistently for the whole Alpine Space in order to prioritise investments.

### *WP4 Reports:*

- "ALPINE RHINE - Water Regime Study in the Alpine Rhine Basin"

No indication was found that climate change induced shifts in the water regime will lead to a widening of the range of uncertainty of the values used in existing design procedures for flood protection measures.

### *WP4 Reports:*

- "Reassessing the reliability of design events in a changing climate"
- "INN - Water Regime Study in the Inn Basin"
- "ALPINE RHINE - Water Regime Study in the Alpine Rhine Basin"

Projections for the middle of the 21st century and the end of the century can differ quite strongly and new information is becoming available all the time. Consequently, planning and implementing protection or adaptation measures should be a cyclical process in which new developments and findings can be taken into account at regular intervals.

*WP4 Reports:*

- “Reassessing the reliability of design events in a changing climate”
- “INN - Water Regime Study in the Inn Basin”
- “ALPINE RHINE - Water Regime Study in the Alpine Rhine Basin”

### 2.3.3 | PROCESS OF CLOSING KNOWLEDGE GAPS

Investments in improved impact modelling and better regionalisation techniques for input, especially precipitation, are “no regret measures” as they serve to reduce risk and uncertainty irrespective of future climate developments.

*WP4 Reports:*

- “Reassessing the reliability of design events in a changing climate”
- “INN - Water Regime Study in the Inn Basin”
- “ALPINE RHINE - Water Regime Study in the Alpine Rhine Basin”
- “ADDA (PO) - Soil Erosion Study in the Adda Basin”
- “DURANCE (RHÔNE) - Understanding Trends in Hydrologic Regimes in the Upper Durance (Rhône Basin)”

For a better assessment of design events a combined approach of statistical and deterministic methods is recommended: Statistical extrapolation of usually very short data records in small Alpine catchments implicates high uncertainties. It is recommended to take catchment characteristics and especially hydrogeologic information into account (e.g. with design storm methods).

*WP4 Reports:*

- “Reassessing the reliability of design events in a changing climate”

Local and regional variability of precipitation and river runoff is very high so there is a continued need for high quality observations and monitoring.

*WP4 Reports:*

- “The AdaptAlp Dataset - Detecting climate-induced trends in observed river discharge data”
- “Reassessing the reliability of design events in a changing climate”
- “INN - Water Regime Study in the Inn Basin”
- “ALPINE RHINE - Water Regime Study in the Alpine Rhine Basin”
- “ADDA (PO) - Soil Erosion Study in the Adda Basin”
- “DURANCE (RHÔNE) - Understanding Trends in Hydrologic Regimes in the Upper Durance (Rhône Basin)”

A better understanding of climate change on the local scale can be achieved by incorporating different scenarios in to impact studies at the regional and local scales.

*WP4 Reports:*

- “INN - Water Regime Study in the Inn Basin”
- “ALPINE RHINE - Water Regime Study in the Alpine Rhine Basin”
- “UPPER SOČA - Water Regime Study in the Upper Soča Basin”
- “Climate Projections for the Greater Alpine Region”

For impact analysis, not only a consistent set of global and regional models but also consistent reference data must be used.

*WP4 Reports:*

- “INN - Water Regime Study in the Inn Basin”
- “Climate Projections for the Greater Alpine Region”



Scientists in climate research should test models according to criteria defined in cooperation with the impact modelling community and set up larger “model ensembles” that allow a probabilistic description of the future and show the high level of variability in the system.

*WP4 Reports:*

- “ALPINE RHINE - Water Regime Study in the Alpine Rhine Basin”
- “Climate Projections for the Greater Alpine Region”

Future water regime studies should not only take climate change but also the many other factors that influence the water cycle, such as land-use, into account.

*WP4 Reports:*

- “ADDA (PO) - Soil Erosion Study in the Adda Basin”
- “DURANCE (RHÔNE) - Understanding Trends in Hydrologic Regimes in the Upper Durance (Rhône Basin)”

To sum up, the members of the AdaptAlp Work Package “Water Regime” group (WP4) recommend a cyclical approach to planning any water related activity or construction that is potentially affected by the local or regional climate. For the Alpine Space, this recommendation should be interpreted in the widest possible sense: The improvement and harmonisation of monitoring networks, the continued development of impact models to integrate all relevant processes, the combination of statistical and deterministic methods, the inclusion of new data and methods from the climate modelling community, a continuous and thorough assessment of local vulnerability to natural hazards with a view to the whole river system rather than isolated areas - all these things can contribute significantly to local communities’ resilience to natural hazards, providing the planning process takes the continuously improving knowledge base into account!

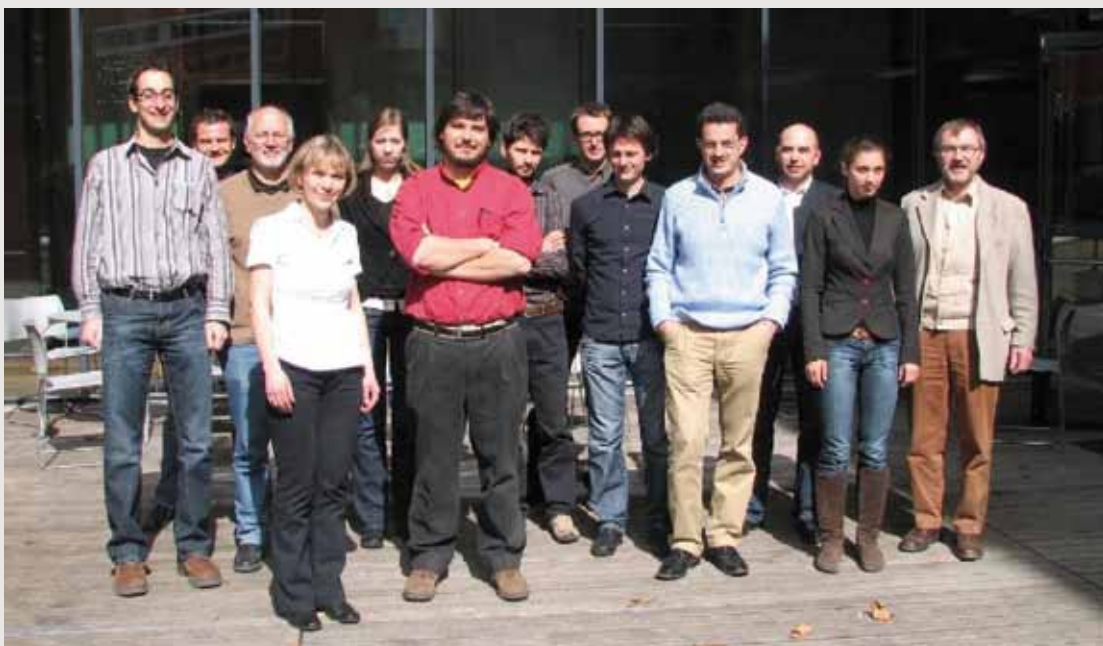


Figure 2.8: The Work Package 4 “Water Regime” group (Bolzano 2010)



## 2.4 | THE WP4 PARTNERS

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## 2.5 | REFERENCES AND FURTHER READING

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2. Reassessing the reliability of design events in a changing climate (Report, AdaptAlp 2011)
3. A Climate Projection for the Greater Alpine Region with a new high resolution Regional Climate Model (Report, AdaptAlp 2011)
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5. Water Regime in the Alpine Space: The Inn Basin (Report, AdaptAlp 2011)
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KLIWA <http://www.kliwa.de/>

KLIWAS <http://www.kliwas.de>

3



# 3. | HAZARD MAPPING

LEAD AUTHORS: FLORIAN RUDOLF-MIKLAU, BARBARA KOGELNIG





## 3.1 | INTRODUCTION

### 3.1.1 | RATIONALE

In the Alpine countries, natural hazards constitute major threats for human activities, settlements and economic areas, transport routes, supply lines and other infrastructure commonly found in the Alpine space. In large parts of the Alps an increasing settlement pressure and area consumption, the opening up of transport routes as well as strong growth rates in tourism have brought about a considerable increase in the spatial extent of endangered areas as well as the increase of values prone to hazards. With the rising demands on welfare and quality of life, the need for safety and protection of the population has similarly increased (Rudolf-Miklau et al., 2011). Furthermore, other human activities (e.g. development for industrial production, urbanization of former rural areas) and climate change contribute to an increase in the likelihood and adverse impacts of hazards (European flood-directive, 2007<sup>2</sup>).

Hazard mapping is an important element for risk management. It provides an effective tool for information and is a valuable basis for spatial planning and further technical, financial and political decisions. Therefore the major task of the project AdaptAlp was the comparison, evaluation, harmonization and the improvement of different methods of hazard mapping applied in Alpine areas. The main focus was hazard mapping of firstly geological and secondly water-related hazards, as there is a considerable lack of standards and requirements for methods and procedures to develop hazard maps in this field. Furthermore, the expected impact of climate change on the temporal probability of those hazards is high. The mandate of Work Package 5 “Hazard Mapping” (WP 5) was the identification of balanced adaptation measures to climate change by improving hazard mapping on a transnational basis, by harmonizing the technical terminology and by creating a basis for cross-sectoral hazard mapping procedures.

### 3.1.2 | HISTORICAL AND LEGAL BACKGROUND

The first hazard maps were established in Switzerland, Austria and France in the 1970s. Since this time considerable effort has been made to improve the hazard mapping techniques in all countries within the Alpine space. Today, hazard maps for floods, debris flows and avalanches are well established and have a legal basis in a lot of Alpine countries, whereas hazard maps for geological hazards (landslides) only exist in exceptional cases. Although there are considerable differences in the management of natural hazards throughout the Alps, the guiding principles of hazard mapping should be generally applicable as the areas prone to these hazards are known or natural hazards are assessed in terms of frequency and magnitude.

Unfortunately, the legal basis for the execution of hazard maps is still weak or non-existent in most countries, as no coherent legal system is in place for mandating the management of natural disasters on the European or international level (Norer, 2011). The challenge is to filter some common elements from these diverse norms, to find the legal essence underlying each norm. Existing norms, however, are often only partly topic-relevant and are following different legal approaches. The “Territorial agenda of the European Union”<sup>3</sup> (Rudolf-Miklau, 2010) outlines objectives for the development of transnational strategies for hazard mitigation (earthquakes, droughts) and the management of risk within areas frequently affected by natural hazards (coastal areas, river basins, mountainous areas). On the Austrian and Swiss national level, hazard zone maps are regulated by legal and technical standards in terms of content, formal requirements, approval procedures and implementation in the development planning. These standards mostly cover the mapping of avalanches and water-related hazards, especially flood mapping.

2 Directive of the European parliament and of the council regarding the assessment and management of flood risks, 2007/60/EC of 23 October 2007, ABI L 288/27 from 6 of November 2007.

3 Territorial Agenda of the European Union – towards a more competitive and sustainable Europe of diverse regions, of 25 May 2007.

### 3.1.3 | SCOPE AND CONTENT

#### *Geological hazards*

Officially approved standards for the hazard assessment of mass movements are still missing in Europe and there is no legal basis available for the definition of areas endangered by landslides or rock fall. The assessment of these processes (e.g. frequency and intensity of events) is difficult and demanding due to the lack of measurements and basic data. In addition, geotechnical parameters, physical properties and triggering mechanisms of the displacement processes are different in every landslide location. Recently, the expansion of settlement areas in Alpine valleys and the growing vulnerability of human facilities have significantly increased the risk of natural disasters caused by mass movements raising risk awareness and protection needs.

Phenomena related to climate change (e.g. permafrost, retreat of glaciers, changes of vegetation cover, torrential rain, snow melt and soil erosion) have an important impact on the triggering and predictability of disasters related to mass movements. The growing demand for hazard maps pertaining to such hazards has initiated strong efforts in all mountainous countries in Europe to develop methods and appropriate requirements that enable the production of hazard maps for mass movements with sufficient accuracy. The ASP (Alpine Space Program/Funding Initiative of the European Commission) project ADAPTALP, in cooperation with other projects such as SAFELAND, PERMANET or MASSMOVE, aims to: (i) facilitate trans-disciplinary and trans-lingual cooperation by providing a multi-lingual and transnational glossary concerning geological hazards (standardized terminology used in the Alpine space), (ii) harmonize the requirements for hazard assessment and mapping of mass movements including the derivation of best practice procedures, and (iii) develop technical minimum requirements for all member states by exchanging experiences in partner regions (Rudolf-Miklau et al., 2011). A basic requirement for geological hazard assessment and the delineation of hazard zones is a detailed knowledge about past (including silent witnesses) and recent events. The knowledge of the past is the main factor for definition of design events, calibration of models and analyzes spatial/temporal probability. This harmonization process involving both Alpine countries and other European countries (Spain, Great Britain) will gain international importance if the European Soil directive<sup>4</sup> initiatives are reached (the latter directive covers landslides and rock fall).



Figure 3.1: Transnational standards in hazard mapping are of major importance for the prevention of catastrophic events (Picture: WLV Vorarlberg).

4 13 Proposal for a Directive of the European Parliament and of the Council establishing a Framework for the Protection of Soil and amending Directive 2004/35/EC, COM(2006) 232 final.2.



### *Water-related hazards*

In contrast to the geological hazards, general objectives for an integrated and sustainable management of floods is defined within the European Spatial Development Perspective (ESDP)<sup>5</sup> and the CEMAT-guidelines<sup>6</sup>. The “European flood directive”<sup>7</sup> specifies these objectives and defines requirements of each member state to produce flood hazard maps, flood risk maps and flood risk management plans according to specified minimum recommendations.

The Directive 2007/60/EC was proposed by the European Commission on 18/01/2006, and was finally published in the Official Journal on 6 November 2007. Its aim is to reduce and manage the risks that floods pose to human health, the environment, cultural heritage and economic activity. According to the EU Flood Directive, Member States will have to reduce flood risk for those areas where the risk is deemed significant. The Directive requires Member States to first carry out a preliminary assessment by 2011 to identify the river basins and associated coastal areas at risk of flooding. For such zones they would then need to draw up flood risk maps by 2013 and establish flood risk management plans focused on prevention, protection and preparedness by 2015. The Directive applies to inland waters as well as all coastal waters across the whole territory of the EU.

Although there is a legal basis and minimum recommendations for hazard mapping in some European countries, there is a continued need for precise data, specified design events and innovative methods that integrate the issue of climate change. Climate change must be considered in order to improve modeling and prediction of natural hazards and impacts in the Alpine space. The primary focus must be the impact of changes in frequency and intensity of catastrophic events and the question of how design events (criteria) for hazard mapping should be adapted accordingly.

A basic requirement for hazard assessment and the delineation of hazard zones is a detailed knowledge about past and recent events. Historical data is crucial for i) the improvement of public awareness, ii) the calibration of models and iii) the analysis of changes in event frequency and the correlation to climate change. Hazard assessment of torrential processes is usually based on historic events and so-called “silent witnesses”, given that modeling is often not feasible and accurate measurement data are generally missing. As archival data is often fragmentary or completely missing, “silent witnesses” (e.g. forms of deposits, indicators in sediments or trees, damage on buildings) offer the possibility to reconstruct past events. Therefore it was the aim to improve the understanding of past, contemporary and potential future hydrogeomorphic processes on fans and cones in Austria through an exploration of existing tools and the documentation of event histories at case-study sites.



Figure 3.2: *Silent witnesses of past torrential activity (Pictures: Barbara Kogelnig).*

- 5 ESDP European Spatial Development Perspective. Towards Balanced and Sustainable Development of the Territory of the European Union, 1999, Section 146.
- 6 The European conference of ministers responsible for regional/spatial planning (CEMAT), 2002, [http://www.coe.int/t/dg4/cultureheritage/heritage/cemat/leaflet\\_en.pdf](http://www.coe.int/t/dg4/cultureheritage/heritage/cemat/leaflet_en.pdf)
- 7 Directive of the European parliament and of the council regarding the assessment and management of flood risks, 2007/60/EC of 23 October 2007, ABI L 288/31 from 6 of November 2007

Analysis of past debris flow, debris flood or flood events has clearly shown that these processes have a variety of process patterns (e.g. morphological changes due to increased local erosion and deposition, clogging of critical flow sections due to woody material accumulations, etc.). Simulation models and design procedures currently used in hazard and risk assessment are only partially able to explain these hydrological differences (Mazzorana and Fuchs, 2009). Therefore, WP 5 has focused on increasing the quality of hazard assessment for water-related hazards by developing a conceptual instrument to conduct retraceable scenario-based hazard analyses. This is an important step towards building climate change adaptation strategies.

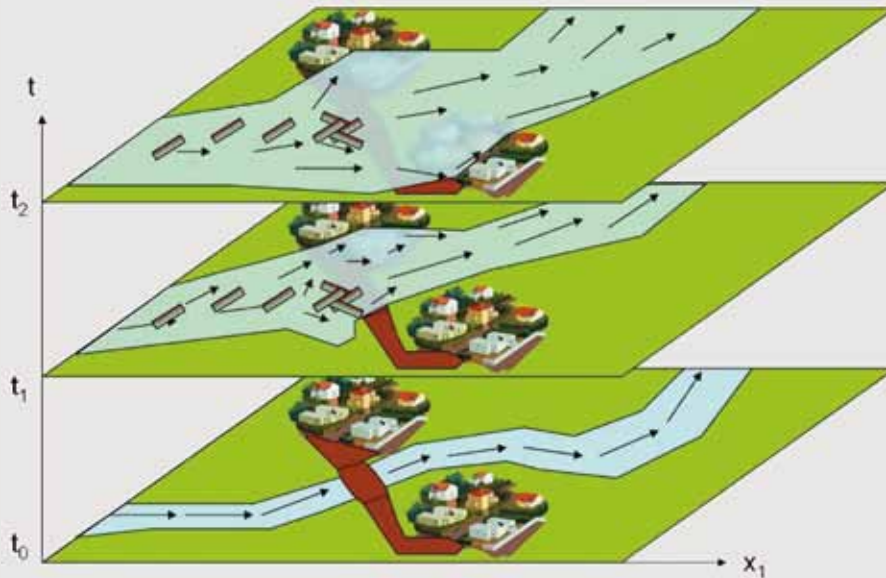


Figure 3.3: Variety of process patterns (clogging of a bridge due to woody material accumulations) and consequences of a flood event by way of example.

The “design event” is the basic concept used in the delineation of hazard maps and for planning of mitigation measures and safety planning. Design events are based on the definition of an event frequency and magnitude, which, however, includes several planning uncertainties – hydrological raw data, fixing of hydrological parameters in order to determine drainage behaviour, presumptions regarding the interaction of extreme scenarios and estimation of sediment transportation, and the effects of drift wood. The fact that effects of climate change are highly uncertainty in defining design events is difficult to avoid. The projects of AdaptAlp have the challenge of developing methodologies that take these uncertainties into account while at the same time complying with the specifications of the European Directive for the assessment and management of flood risks.

### Synthesis

Within a final workshop, the knowledge, results and findings gained in Work Package 5 were summarized and general strategies and recommendations for adaptation of hazard mapping to Climate Change were developed. The obtained recommendations about the adaptation of hazard assessment, hazard mapping methods and the application of hazard maps to a changing environment were presented within a comprehensive factsheet.

## 3.2 | MAJOR FIELDS OF INVESTIGATIONS AND FINDINGS

The purpose of hazard maps is the topographical identification and illustration of areas at risk. Within WP 5 “Hazard mapping” the main objective is to assess, evaluate and harmonize approaches and methods of hazard mapping applied in the Alpine space under the consideration of climate change. In order to fulfil these ambitious goals, the project partners have been working on four different fields of investigation: data and classification, hazard assessment, planning procedure and adaptation measures. As described above, there exist fundamental differences concerning legal aspects, available procedures, tools and models for hazard mapping of geological and water-related hazards. These differences lead a subdivision of the field’s data and classification, hazard assessment and planning procedures according to the processes (see Table 3.1).

	DATA AND CLASSIFICATIONS	HAZARD ASSESSMENT	PLANNING PROCEDURE	ADAPTATION
Geological hazards	Multilingual glossarys	Models change	Minimum requirements	Recommendations
Water-related hazards	Dating methods	Scenario based hazard assessment	Methodology and structure	

Table 3.1: Fields of investigation in WP 5 concerning hazard mapping

These seven main fields of investigation had been subdivided in 25 single activities, enabling a structured and efficient working progress.

### 3.2.1 | STANDARDIZATION (HARMONIZATION) OF TERMINOLOGY CONCERNING GEOLOGICAL HAZARDS IN EUROPE

#### *General description*

Purpose and motivation for this part of the project are the difficulties traditionally encountered when using or defining mass movement terms in scientific work. This results in different methods and concepts being used by geological agencies and finally leads to misunderstanding and problems within cooperative international projects. In order to tackle that complexity and ambiguity, found not only in the German-speaking geology, but generally throughout Europe, a multilingual glossary was created. This glossary aims at an international harmonization by providing the user with a selection of official terms used by the geological agencies in a specific country and by setting relations to synonymous terms employed in other countries.

The work on the glossary was divided in two main parts. The first step was to design and implement the infrastructure required to store and query the terms. For this purpose, a relational database management system was created as a back-end. In the second step the terms and definitions were elaborated from the responsible experts in each of the eight involved countries. Each contribution was developed with the help of native speakers on the basis of a German glossary table and includes the language English, French, German (Germany, Switzerland, Austria), Italian, Slovenian and Spanish (Castellano, Catalan).

#### *Objectives*

With reference to the main objectives of WP 5, which targets an improvement of harmonized technical terminology and unified approaches and methods of hazard mapping a multilingual harmonized glossary to landslides is certainly a very important tool. The glossary will help experts, practitioners and decision makers to improve the understanding and traceability for approaches and methods dealing with “Climate Change problems” in their-own and other countries.

Altogether the multilingual glossary will help to facilitate the international cooperation in projects dealing with landslides and geological hazards and supports the transnational exchange between practitioners and facilitates knowledge-transfer in a correct way with minimum misunderstandings. In other words: The glossary overcomes the “Babylonian confusion” in geological terminology and supports “semantic cohesion” in the ASP.

### Major findings and specific recommendations

Concerning to the technical implementation of the glossary it was very important to mind the fact that the usage of terms in general and the definition of similar terms can be different in the involved countries. Therefore it was essential to assess the exact requirements for the glossary before the database was designed. At first a list of attributes needed for a single glossary term as well as a type for those attributes (e.g. numbers, text, keys etc.) was defined. The type of attribute determines which relations can be saved in the database and what kind of information can be queried using them. Because of the pan-European character of the glossary, it was necessary to specify the languages more precisely by linking them to a specific country, resulting in a unique combination for one language and one country. It was particularly relevant for this project, as the usage of a term varies greatly within a language depending on the region where it is used, as it is the case for German (Germany, Austria, and Switzerland). Editing and adding glossary terms after the initial import is also possible and requires saving metadata for each entry, e.g. time and date of the creation or the last edit of a term. Usually the classical approach followed by most glossaries is a single translation layer; a direct translation of each term into exactly one term of another language. This corresponds to a 1: n relation between the entities (i.e. glossary terms) in an Entity-Relationship-Model (ERM). Such a direct translation supposes an equivalence of the terms definition and meaning. In this new glossary, the relations between the different terms are defined solely by their technical meaning, resulting in two possible relations: same meaning or similar meaning. A direct translation is still required in order to provide the user with the exact translation of a definition in his language.

To fill this complex database-structure the approach in getting the topics had central importance. Unlike many other glossaries, which are rather dictionaries working with direct translation, this glossary is consisting of terms and definitions which are not necessarily have to be part of a nomenclature or literature, but really be used by the official agencies within the involved countries. For the development of such a glossary it was unavoidable to create a “basic - list” in which all the desired terms and definitions are included. Therefore a table with 97 terms and definitions to geological hazards (in German) was elaborated. Based on this the, a so called “harmonization” into the other languages was made. Basically this data acquisition was made within short visits in the involved countries. Building on the German “Basic-list” within these talks “term after term” was discussed with the respective person responsible. With regard to linguistic problems each “Harmonization” is carried out with the help of native speakers who also be well versed in the thematic of geological hazards. In a last step the relations (same, similar, not existing) between the different languages were set manually term by term.

Figure 3.4: Graphical User Interface of the glossary. (<http://www.lfu.bayern.de/geologie/massenbewegungen/glossar/index.htm>).

Altogether the major findings of this glossary can give an important contribution to one of the main goals of the whole project, namely the improvement of the cooperation by the European countries in dealing with geological hazards by finding a common language. Our glossary can be called a “geohazard babble-fish”.



## 3.2.2 | MINIMUM REQUIREMENTS OF GEOLOGICAL HAZARDS MAPPING

### *General description*

Hazard mapping is an important element in risk management. In dealing with geological hazards today, geotechnical (active; preventive or remediation) and spatial (passive; preventive) measures come to implementation to minimize risk. Because of a time limitation of active measures (e.g. protective walls) and the decrease of space for permanent settlements, spatial planning gets more and more important.

Countless types of “Susceptibility, Hazard and Risk maps” are produced for all kinds of risks. With regard to geological hazards a large variety of maps and methods are used in the different European countries to prevent natural disasters. This variety reaches from simple susceptibility mapping to legally binding “Hazard Zone Plans”. The main goal of work package 5.1 is the assessment and comparison of hazard mapping methods in CH, AT, IT, FR, SI, DE, GB and ES, to evaluate procedures for the creation of geological hazard maps and, validate the reliability these maps in order to elaborate minimum requirements for geological (digital) susceptibility, hazard and risk mapping and related databases.

The first step to reach this ambitious goal was the evaluation of the status quo in susceptibility and hazard mapping in each involved country. Two main questions had to be answered:

- What kinds of susceptibility, hazard and risk maps are officially applied in each country?
- Which standards are these maps based on?

To answer these questions each participant gave a detailed overview of the official used susceptibility, hazard and risk maps and also information to the method of creation of such maps and the used input data.

In the second step common definitions for susceptibility, hazard and risk maps had been elaborated within a extensive literature research about all terms concerning landslides, susceptibility maps, hazard maps and risk maps. The study has been attended by a general literature research concerning methods of hazard mapping and evaluation of hazard by landslides. The literature research was a basis for the carried out work and provided a first overview for the evaluation of measures carried out in the different involved countries. The topics had been landslide inventories, inventory maps, landslide susceptibility maps, hazard maps, specifications of design events, assessment of potential processes, content of general legends and a list of relevant terms.

The third step was to show in what extend the different maps in the different countries correspond to the elaborated definitions. And the last step was to define the minimum requirements for the creation of susceptibility, hazard and risk maps concerning the methods and input data, to elaborate a common database denominator including unified, common basic standard and extent that landslide database should have.

Finally the methods and developed tools were assessed within a special publication of the Journal for Torrent and Avalanche Control. In the publication “Alpine Mass Movements: Implications for hazard assessment and mapping” (BMLFUW, 2011) all standards and methods for hazard mapping of geological hazards applied in the Alpine space are described by the partner and observer of AdaptAlp.

### *Objectives*

In spite of different methods in creating susceptibility, hazard and risk maps for geological processes, the necessity of these maps as a tool of hazard prevention is generally accepted in Europe. Scientific characterization of mass movements and identification of areas prone to landslides with comprehensible methods is the most important task in this field of work.

One of the main objectives of the Action 5.1 was to give definitions of the terms susceptibility, hazard and risk maps accepted by all participants. This was the assumption for the next important objective to point out the differences and similarities for better comparability of the different types of maps in the involved countries. On this wide spreading consensus it was possible to formulate minimum requirements for the creation of susceptibility, hazard and risk maps.

## Major findings and specific recommendations

Common definition of the terms susceptibility and hazard map:

### Landslide Susceptibility Map Level 1:

A Landslide Susceptibility Map (Level 1) is used for the first identification of areas showing conflicts of interests or areas under suspicion to be hazardous. It is a map created on objective, scientific criteria with information on hazard susceptibility, which are not analysed, identified and localised in detail. With empirical, statistical or deterministic methods these maps show the basic disposition for the development of landslides. In general only the potential detachment zone of the landslides is shown and no classification of different hazard levels (probability and intensity) is done.

### Landslide Susceptibility Map Level 2:

A Landslide Susceptibility Map (Level 2) is used for the first identification of areas showing conflicts of interests or areas under suspicion to be hazardous. It is a map created on objective, scientific criteria with information on hazard susceptibility, which are analysed, identified and localised. With empirical, statistical or deterministic methods these maps show the basic disposition for the development of landslides. In general the whole process areas of the landslides and the propagation areas are shown (potential detachment and runout zone) and no classification of different hazard levels (probability and intensity) is done.

### Hazard Map:

A Landslide Hazard Map builds the base for urban land use planning and the development and the costing of protective measures. It is a map created on objective, scientific criteria with information to hazard, which are analysed, identified and localised in detail. With empirical, statistical or deterministic methods in general the whole process areas of the different types of landslides, including the propagation areas are considered (potential detachment and runout zone) and a classification of different hazard levels based on probability and intensity is done.

Country	Process	Landslide Suscep. Map (L1)	Landslide Suscep. Map (L2)	Hazard Map
Germany (Bavaria)	slide			Susc. Map (1:25.000)
	fall			Susc. Map (1:25.000)
	shallow landslides		Susc. Map (1:25.000)	
Austria (WLV)	slide			Hazard Zone Map (1:2.000)
	fall			Hazard Zone Map (1:2.000)
	shallow landslides			Hazard Zone Map (1:2.000)
Austria (GBA and Carinthia)	slide	Susc. Map (1:25.000-50.000)		Hazard Zone Map (1:1.000-1:10.000)
	fall	Susc. Map (1:25.000-50.000)		Hazard Zone Map (1:1.000-1:10.000)
	shallow landslides	Susc. Map (1:25.000-50.000)		Hazard Zone Map (1:1.000-1:10.000)
Switzerland	slide		Susc. Map (1:10.000-1:50.000)	Hazard Map (1:2.000-1:10.000)
	fall		Susc. Map (1:10.000-1:50.000)	Hazard Map (1:2.000-1:10.000)
	shallow landslides		Susc. Map (1:10.000-1:50.000)	Hazard Map (1:2.000-1:10.000)
Great Britain (BGS)	slide	Susc. Map (1:10.000-1:50.000)		
	fall			
	shallow landslides	Susc. Map (1:10.000-1:50.000)		
Italy (Arpa Piemonte)	slide			Atlas of Hydrogeological Risk (1:10.000)
	fall			Atlas of Hydrogeological Risk (1:10.000)
	shallow landslides			Atlas of Hydrogeological Risk (1:10.000)
Italy (South Tyrol)	slide			Hazard Plan (1:5.000-1:10.000)
	fall			Hazard Plan (1:5.000-1:10.000)
	shallow landslides			Hazard Plan (1:5.000-1:10.000)
Italy (Emilia Romagna)	slide			Susc. Map (1:10.000)
	fall			
	shallow landslides	Susc. Map (1:10.000)		
Spain (Catalonia)	slide			Geological Risk Prevention Map (1:25.000)
	fall			Geological Risk Prevention Map (1:25.000)
	shallow landslides			Geological Risk Prevention Map (1:25.000)
Slovenia	slide	Susc. Map (1:250.000)		Hazard Map (1:25.000) in progress
	fall	Susc. Map (1:250.000)		Hazard Map (1:25.000) in progress
	shallow landslides	Susc. Map (1:250.000)		Hazard Map (1:25.000) in progress
France	slide	Plan for Prevention of Natural Hazard (1:25.000)		Plan for Prevention of Natural Hazard (1:10.000)
	fall	Plan for Prevention of Natural Hazard (1:25.000)		Plan for Prevention of Natural Hazard (1:10.000)
	shallow landslides	Plan for Prevention of Natural Hazard (1:25.000)		Plan for Prevention of Natural Hazard (1:10.000)

Table 3.2: Scale of susceptibility/hazard maps in the different countries corresponding to the elaborated definitions.



*Common database denominator:*

Knowledge of past and recent events is the basis for definition of design events, spatial/temporal probability and public awareness. Landslide databases are therefore mandatory to ascertain landslide susceptibility, hazard and risk.

A central landslide database is a basic requirement for hazard assessment, for documentation of landslide occurrences and processes in details as much as possible.

The main objective of establishing a common database denominator is to ensure the recollection of past events to identify dangerous areas and to decide mitigation measurements. The database also represents the basis for spatial analysis of slope mass movement distribution and serves as a foundation for the modeling and production of geo-hazard and geo-risk maps of different scales.

		Slide processes			Fall processes						Shallow landslides					
		Landslide Susceptibility Map		Hazard Map	Landslide Susceptibility Map				Hazard map		Landslide Susceptibility Map		Hazard Map			
		Level 1	Level 2	Haz. map	single block	Level 1	Level 2	Level 1	Level 2	single block	rock masses	Level 1	Level 2	Haz. map		
										Hazard map						
Geological maps and derived products	Geological map															
Landslide inventory in the broadest sense	Landslide inventory (e.g. Database/ Inventory Map)															
	Field work (Validation /Investigation)	GREEN														
Elevation models /areal photos	Elevation model															
	Optical, aerial photos (Orthophotos)															
	LIDAR (terrestrial)															
	LIDAR (airborne)															
	Elevation model															
Modeling in the broadest sense (slides can be found by field investigation)	Modeling				D	D+P	D	D+P	D+P	D+P	D	D+P	D+P			
	Modeling deterministical				D	P			P	P	D	D+P	D+P			
	Modeling statistical				D						D	D+P	D+P			
	Modeling empirical				D	D	D	D+P	D	D+P						
Probability (spatial and temporal probability must be unified in a matrix. Information can be qualitative)	Spatial probability in the process area															
	Temporal probability															
Intensity (Information can be qualitative)	Empirical determination															
<b>LEGEND</b>		<b>RED</b>			Basic data or method is mandatory						<b>GREEN</b>			One out of several methods must be used		

Table 3.3: Minimum requirements for the different maps and different processes

*Minimum requirements for different maps and different processes:*

To work out the minimum requirements for the landslide susceptibility maps and hazard maps in each partner country interviews had been made and questionnaires had been filled out. Based on the results for every country a list had been compiled in which the characteristic parameters, basic data and used methods to create the maps are shown. The lists are distributed on the AdaptAlp homepage.

Based on these lists the minimum requirements for the different maps had been developed within a workshop, held in Munich, December 2010.

### 3.2.3 | DEVELOPMENT, APPLICATION (TESTING) AND COMPARISON OF MODEL AND DATASETS IN MODEL REGIONS

#### General description

The assessment of geological hazards (rockfall, landslides, etc.) often lacks on sufficient measurement data and the assessment of these processes concerning frequency and intensity of events is difficult. Due to the growing demand for hazard maps has initiated strong efforts within AdaptAlp to develop, test and compare different models and datasets that enable the production of hazard maps for mass movements.

As a first step the variables and parameters needed for application of quantitative models for hazard assessment related to different landslide typologies were identified. Shallow rapid landslides normally occur on slopes covered by thin colluvium and exhibit an initial translational sliding failure and a subsequent disaggregation to form into a debris flow. This soil slide-debris flow movement is the most commonly observed failure mode involving colluvial slopes. Despite the modest volume involved, shallow landslides appear very dangerous due to their velocity consequent to mobilization. Extensive investigation emphasizes the following general aspects and characteristics related to this kind of landslide:

- high number of slides (sometimes more than one thousand) triggered by one rainstorm;
- high spatial concentration (often more than 150 slides/km<sup>2</sup>);
- very high velocity consequent to mass mobilization (sometimes over 50 km/h);
- very high potential destructive impact;
- many slopes having 25°– 45° dip and over are affected by shallow rapid landslides; short range in time between the initial movement and the stop of the mobilized mass;
- long distance reached (in many cases) by mobilized mass until deposition occurs;
- principal triggering factors on heavy rainstorms with high rainfall intensity and quite long duration (sometimes more than 24 h);
- absence of incipient movement evidence

Based on the identification of variables and parameters needed for application of quantitative models for hazard assessment, an application of different quantitative hazard models for different landslide typologies plus an application of slope stability and hazard assessment models for each landslide typology was performed (Nicolò and Campus, 2010; see Figure 3.6).

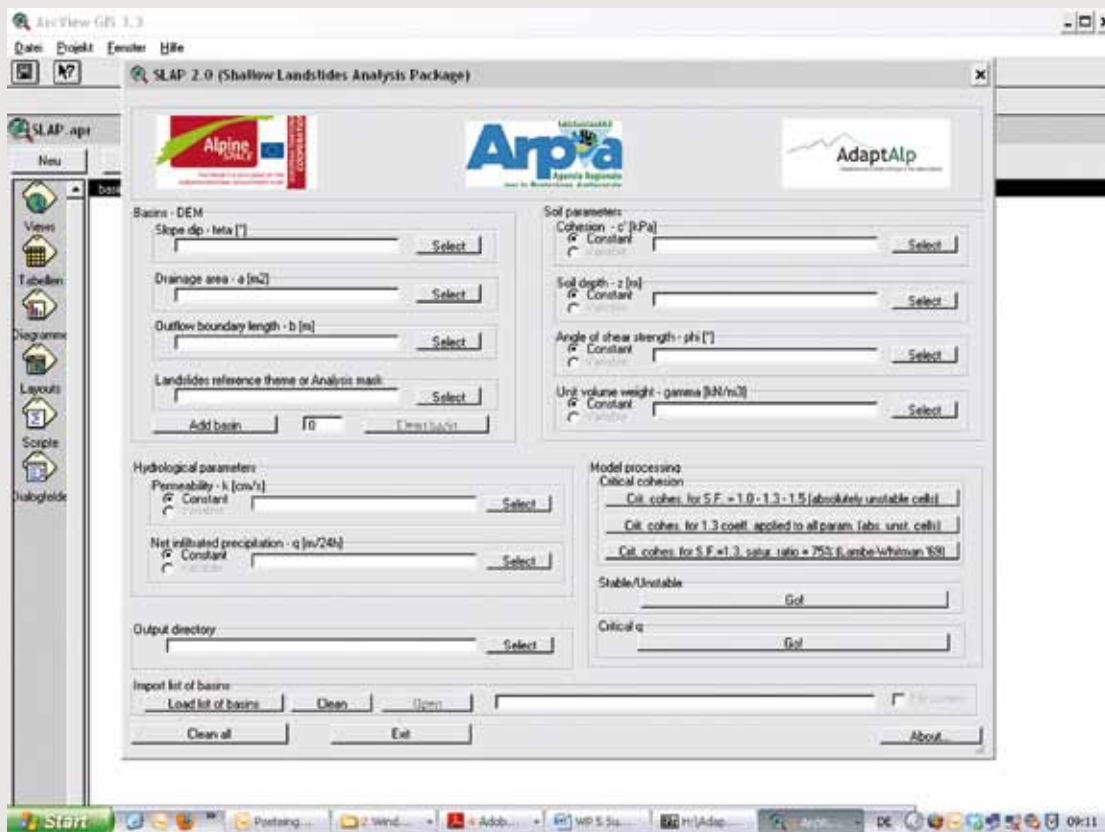


Figure 3.5: Graphic user interface (GUI) of SLAP extension.

In addition, semi-automatically identification of rock-fall and landslide susceptible areas was developed, especially suitable for spontaneous landslides in loose materials. This project was performed within the area of Gasen/Haslau, which offers on the one hand a very good database and on the other hand was affected by numerous landslides in August 2005. Single steps included evaluating several databases and the potential of new technologies like remote sensing technologies as LIDAR (Airborne Laser Scanning) and VHR (very high resolution) satellite images, with reference to the landslide relevant information content and subsequently, developing, improving and comparing different methods of area-wide spontaneous landslide assessment in loose material.

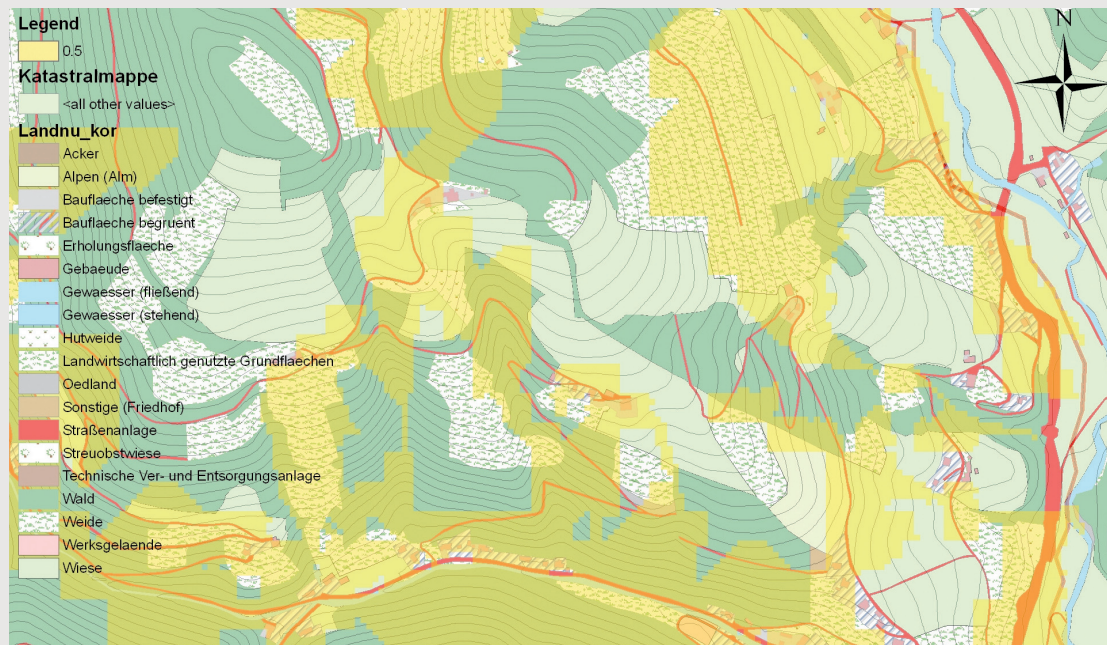


Figure 3.6: Map of the semi-automatically analysis of rock-fall and landslide susceptible areas of the area of Gasen/Haslau

Antecedent rainfall plays an important role in triggering landslides. Therefore, the spatio-temporal factors influencing slope mass movements in central Slovenia were analysed regarding the influencing factors governing their occurrence. Analyses revealed that minor a part of slope failures occurred as a consequence of rainfall over a certain period. There are also exceptions, such as when daily rainfall exceeds antecedent rainfall, however these occurrences are rare (about once every 100 years). Within the research area, the landslides have been triggered when the rainfall threshold exceeded 5-day antecedent rainfall and analyses revealed that the required rainfall ranged from 115 to 160mm. The proposed threshold model is based only on antecedent rainfall, but if a model introduced other important factors which also significantly influenced landslide occurrence (i.e. slope, hydrology, soil moisture, topography and soil thickness) the value of the threshold model would be changed, and likewise if the temporal and spatial distribution of rainfall has a different appearance. In this case, only data from daily rainfall is available and can serve as a warning of possible slope failure. The present model could be useful anywhere in the Alpine Space, or even in the world. The only requirement is that historical data sets of rainfall and landslide data are recorded. Therefore, one of the important tasks in the future for those institutions dealing with prevention against slope failures, could be determining the rainfall threshold, characterising significant differences between observed areas and trying to find out areas with high or low vulnerability to landslides.

All these methods, procedures and models were established within continuously exchange of data and experienced concerning the improvement of models and databases. Within several meetings, conferences and workshops a transnational network was established and by providing the data of Gasen-Haslau to the project partners in order to test the behaviour and adaptability of their models, possibilities and limits for the transferability of models were asserted.

### *Objectives*

Frequent slope mass movements constantly pose new challenges to experts who try to assess the dynamics and triggering mechanisms and perform monitoring of such phenomena. Landslides have complex dynamics that vary through space and time. Assessment of past displacements is usually not possible, since classical methods of measurement only collect data from the moment they are mounted. Experts are faced with a challenge: how to examine and study processes that have already occurred and that were not monitored with classical geotechnical methods? Another problem is that continuous monitoring over a wide area is difficult, due to lack of resources. Classical geotechnical and geodetic approaches, combined with GIS and remote sensing, enable innovative approaches to overcome these challenges (Komac et al., 2011).

The usage of digital tools for handling spatial data such as GIS, GPS and Remote Sensing is “state-of-the-art” in practically all research on landslide susceptibility and hazard mapping. These tools also have defined, to a large extent, the type of analysis that can be carried out. It can be stated that to a certain degree the capability of GIS tools and the accuracy of the in-situ and remote sensing data have determined the current state of the art in landslide hazard and risk assessment.

For a correct calibration of these tools, the focus was to assess the influence of specific factors and the effects of certain parameter combinations on landslide occurrences and to produce a simple but reliable (robust) landslide susceptibility model as a basis for sustainable spatial planning. Consequently, as being the most important triggering factor for landslide occurrences the precipitation parameter was related to slide occurrences and analysed as a function of time in order to implement the temporal component into the susceptibility model and bring them closer to hazard models.

### *Major findings and specific recommendations*

The development of landslide susceptibility models and in later the stages of hazard and landslide risk modeling represents a helix, which reaches new and better level of reliability and correctness with every new step (a discovery, data, improvement of modeling). Reliable and high quality model is a foundation of sustainable spatial planning at different scales. As anticipated, results of susceptibility prediction on regional scale do not achieve prediction levels of landslide susceptibility models on a local scale, since the data are coarser in the first case. Despite that they represent a good synoptic overview of the landslide susceptibility in Slovenia and form a solid foundation for spatial planning at a warning level.

The results showed that three factors play very important roles, lithology, slope, and land use. Lithology plays the most important role, followed by slope and land use type. Although the latter is the least important factor among the three, it is essential for good landslide susceptibility prediction and cannot simply be excluded from the model. Using only these 3 factors models would not achieve the best prediction performances in comparison to the models with more factors since the detail of the model would be lost to a certain degree, but the results would still be satisfactory. It is recommended that at least these three factors are used when performing landslide modeling.

At more detailed scales the inclusion of the factor that describes the synchronism of geological strata dipping with slope aspect and inclination would substantially elevate the performance of prediction, but at the time being detailed regional collection and latter the modeling of strata dipping data on a regional scale is time consuming if not almost impossible. Inclusion of this factor would only be logical and feasible at detailed level, i.e. at scale 1:25,000.



### 3.2.4 | IMPROVING DATING METHODS OF PAST EVENTS

#### *General description*

Appropriate hazard assessment of hydrogeomorphic processes mainly demands knowledge about event frequency and magnitude (Jakob and Bovis, 1996). At present, there are no rigorous methods available which would allow determination of event probability, be it based on physically measured characteristics of a catchment or on statistical approaches (Rickenmann, 1999). The most accurate basis for hazard and risk assessment on fans and cones is a detailed knowledge of past and contemporary events.

Archival data of past events often lacks spatial and temporal information, satisfying resolution or precision, and is biased towards events that caused damage to structures or loss of life on one hand and is undersampled in unpopulated areas on the other hand. Additional bias is introduced when interviewing residents because human memory is short-lived and highly selective, and the record will be biased towards more frequent events in the recent past. Therefore, archival records should be supplemented with other techniques (Jakob, 2005). As archival records are often fragmentary, “silent witnesses” in the form of deposits or registered in sediments, trees, or marks on building can be of key importance for a better understanding of process dynamics and activity. It is also obvious that climate and climatic change play their role in affecting both the frequency and magnitude of hydrogeomorphic processes in mountainous environments, but an apprehension of the influence of these processes is difficult if only limited data is available on past events, their size and triggers.

Therefore it was the aim to establish a “state-of-the-art” report for practitioners about “Tracking of past events on fans and cones: dating techniques and applications” in order to include “silent witnesses” into hazard and risk assessment. Selected methods developed and described within this report had been tested within three extensive case studies in Austria (see Figure 3.2, example of the debris flow frequency in the Gratzental-Valley).

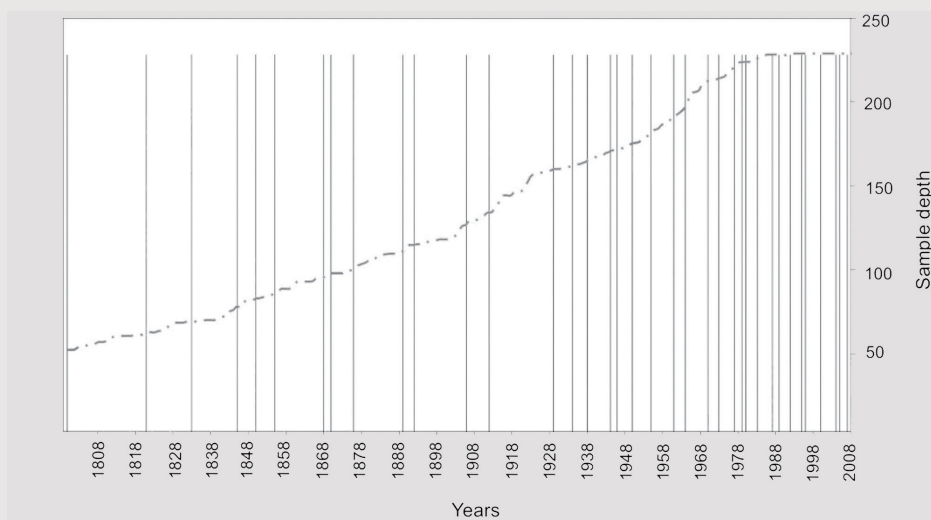


Figure 3.7: Minimum frequency of debris flood events for the Gratzentalbach. Each vertical is representing a debris-flood event; the number of increment cores available for the analysis at any moment in the past is shown by the dot-dashed line indicating sample depth. The reconstruction of past events is based on tree-ring analysis.

#### *Objectives*

It was the aim of the studies to improve the understanding of past, contemporary and potential future hydrogeomorphic processes on fans and cones through an exploration of existing tools. Modern dating methods include a wide range of different sciences and high-tech procedures such as dendrogeomorphology, vegetation analysis, lichenometry, cosmogenic nuclides, radiocarbon dating or varves. The application of most of these methods was reserved to scientific investigations so far. Only simple and low-cost dating methods (e.g. “silent witnesses”, archival records, digital images) have been already implemented in the hazard assessment of engineering purposes. In order to gain a comprehensive over-view and to be able to provide a “state-of-the-art” comparison an expert poll was carried out. Leading specialists from Europe and America were invited to contribute to this survey of methods providing a questionnaire and universal criteria for the evaluation of practical applicability of each method. The methods were assessed and compared concerning – among other criteria – their characteristic, the time period covered, the temporal resolution, the assessed type of data (frequency, magnitude, spread of process), the costs, the duration, the general scope of application and



the limitations (prerequisites for application). The handbook for practitioners about “Tracking of past events on fans and cones: dating techniques and applications” should improve hazard and risk assessment by including “silent witnesses” into the assessment procedure. The farsighted goal of this study was the provision of reliable methods for event dating in order to enable condensed data sets for accurate prognosis of future catastrophic events. The reduction of uncertainties concerning the frequency of catastrophic events will contribute to a better understanding of the impact of climate change on the triggering mechanisms of water related hazardous processes.

Within three extensive case studies the debris-flow frequency in the Austrian Alps was investigated by means of dendrogeomorphology. The results show clearly that dendrogeomorphology has a considerable potential to add substantially to event chronologies of past debris-flow activity over periods beyond written records and improves understanding of process activity in complex situations. In addition, the approach also allowed assessing the changes in debris-flow frequencies under the influence of climate change.

#### *Major findings and specific recommendations*

It can be concluded that the inclusion of “silent witnesses” in the form of dating techniques in general and dendrogeomorphology in particular have a great potential for improvement of hazard and risk assessments. Approaches should be more often used to improve databases and the knowledge of local process dynamics.

This “state-of-the-art” report will help practitioners to better apprehend and understand the possibilities and limitations of dating techniques on fans and cones; and therefore better estimate return intervals, spatial patterns, the reach or trigger of hydrogeomorphic processes.

### 3.2.5 | SCENARIO BASED HAZARD ASSESSMENT UNDER CONSIDERATION OF CC

#### *General description*

Analysis of past debris flow, hyperconcentrated flow or flood events clearly showed that these processes have a variety of process patterns involving morphological changes due to increased local erosion and deposition phenomena, as well as clogging of critical flow sections due to woody material accumulations. The increasing area consumption and the expected increase of extreme events due to climate change will furthermore exacerbate this situation.

Simulation models and design procedures currently used in hazard and risk assessment are only partially able to explain these hydrological cause-effect relationships because the selection of appropriate and reliable scenarios still remains unsolved (Mazzorana and Fuchs, 2009). Therefore it was one objective within work package 5 to increase the quality of hazard assessment for water-related hazards by developing a conceptual instrument to conduct retraceable scenario-based hazard analysis and therewith offering a climate change adapting strategy.

In a first step the conceptual background for the development of a scenario-based hazard analysis has been clarified defining general principles to perform coherently the analysis at different spatial scales. In a second step, a series of case studies have been carried out to highlight the general applicability and the procedural rationality of the proposed methodological approach. Additionally, a GIS-based analysis and interpretation of hydrological model results was performed including the scenario-based principles.

Meeting the demands of a fast analysis of the possible response in terms of sediment availability of alpine catchments to the impact of climate change (e.g. system changes leading to receding permafrost layers or augmented sediment inputs through landslides) a software tool has been realized. Turning the attention to a more detailed level of investigation, case studies show how to practically perform step by step a scenario-based hazard analysis for torrents and for river-systems. The circumstance that woody material transported during extreme events exacerbates the flood intensity during extreme events and that the behavior of protection measures has been explicitly treated by formulating dedicated modeling approaches.

### Objectives

The link between climatic changes, the modified occurrence and unfolding of water-related natural hazard processes is widely acknowledged and the implications for decision making at various levels cannot be neglected anymore. In parallel existing quantitative information about natural hazards is of heterogeneous quality and reliability. This is partly due to the fact that different legal frameworks exist for the elaboration of hazard maps. Moreover at a more basic level currently used analysis procedures are not sufficient to accurately mirror spatial probability and intensity of the considered water-related processes. Obvious repercussions on the land-use planning activities and more directly on the elaboration of mitigation strategies are foreseeable. Consequently fundamental methodological advances are required to improve the traceability and the comparability of quantitative hazard assessments. These seems to be undeniable in the light of the fact that a complete harmonization of the legal frameworks (and its implementation), although theoretically desirable, is unrealistic for practical reasons.

The indispensable objective of a coherent methodological foundation implies that the basic principles have to be traduced into user-oriented guidelines to enhance a smooth applicability. Also the aforementioned second objective entails the need for exemplified case studies as reference to orient the practical activities.

Within the framework of natural hazard risk the reliable determination of specified hazard scenarios is not only a cornerstone but also the essential point of departure, therefore minimizing uncertainties from the very beginning is fundamental.

This project aims at developing an effective assessment concept for the feeder/receiving water system, while taking the basic concept of the extended formative scenario analysis into account (Mazzorana and Fuchs, 2009). In doing so the legal framework, the current state of scientific knowledge and aspects of economic efficiency are considered. In order to ensure coherency, the terminology used in the extended formative scenario is also used in the current scenario analysis concept.

### Major findings and specific recommendations

Water-related processes can have a variety of process patterns involving morphological changes due to increased local erosion and deposition phenomena, as well as clogging of critical flow sections due to woody material accumulations. The currently used design procedures and simulation models can at most partially consider this variety in process patterns. By introducing a methodological meta-structure to effectively perform the process routing and to derive a reliable set of consistent scenario evolution trajectories in mountain streams (i.e. loading system – LS) and to delineate the subsequent inundation patterns on alluvial fans and floodplains (i.e. response system – RS) enables a multi-level knowledge-integration approach. The proposal of distinct procedures for the definition of LS and RS, respectively, help to progressively reduce the structural shortcomings affecting the hazard assessment procedure.

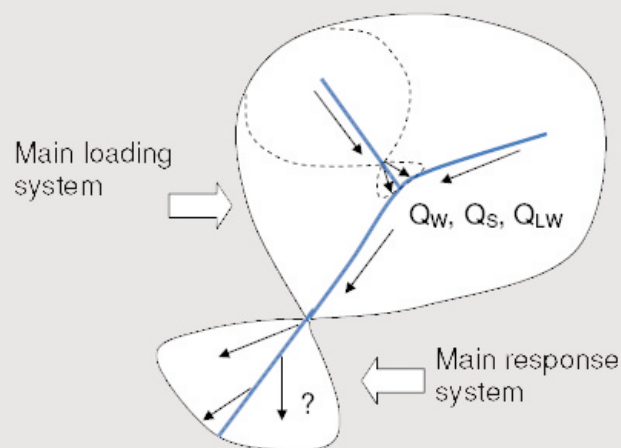


Figure 3.8: Sketch representing a basin (i.e. the main loading system) where channels are mostly confined by hillslopes and the direction of flows ( $QW$ , water discharge,  $QS$  sediment discharge,  $QLW$  driftwood discharge) is mostly unambiguous, and its alluvial/debris fan (i.e. the main response system) where the channel is unconfined and therefore flows present more possible directions during flood events. A loading/response systems (i.e. the sub basin with its small fan) nested within the main system is also represented.

The principles for a scenario-based hazard assessment provide guidance for talking specific problems related to hazard assessment and constitute a conceptual bridge to multi-hazard assessment. That means that the most general principles are valid also for the assessment landslides. Step by step references to specific techniques (e.g. Formative Scenario Analysis) are provided to effectively convey process-specific knowledge generation through a balanced synthesis of different knowledge sources.

## 3.2.6 | LINKING HAZARD TO RISK: TOOLS AND CASE STUDIES

### *General description*

Flood hazard maps are the basis for the planning of protective measures, the development of emergency action plans and are also used as a basis for regional planning, building regulations and risk management. The uncertainty in developing these flood hazard maps will increase as a result of the progressing climate change. Apart from the existing planning uncertainties, such as hydrological raw data, the fixing of hydrological parameters in order to determine drainage behavior, the presumptions regarding the interaction of extreme scenarios, the estimation of sediment transportation and the effects of drift wood, climate change causes a further not appraisable uncertainty. The projects in the AdaptAlp therefore aim to develop methodologies, which take these uncertainties into account when assessing the designation of hazard zones, while at the same time complying with the specifications of the European Flood Directive.

In the context of the project “Linking hazard risk: tools and case studies” a methodology and structure of a toolbox for risk analyses as an ArcGIS PlugIn based on hazard maps and a defined catalogue of objects worth to be protected have been elaborated. The results are the extraction of the concernment of objects worth to be protected based on hazard maps. This tool represents the basic instrument for the risk management planning.

Based on the toolbox on the municipal level an integrated view over different natural processes (flood, geology, torrents, debris flow and avalanche) were carried out. The results are factsheets with a description and structure how such an integrated view could look like

In order to test and apply the developed approaches in model regions, three case studies on municipal level in Carinthia have been realized. The experiences with the toolbox and the integrated view over different natural processes were summarized in a factsheet.

As the behavior of torrent control protection measures is a critical factor at the interface between occurring natural hazard processes and impacts in terms of risk, the structural vulnerability of protection measures has been evaluated within a second case study and summaries in a report. In fact protection structures exhibit a dual nature. On the one hand they are a key element for the reduction of hazard frequency and intensity but on the other hand, as a consequence of their structural vulnerability, they can contribute to increase the overall risk. This is true for two reasons: (1) the protection structure has an intrinsic economic value and is an element at risk; (2) an accentuation of hazard process intensities can result from structural failure and in turn risk is augmented. This was one of the main findings of the study. Moreover it was possible to identify consolidation structure typologies which are particularly prone to failure.

### *Objectives*

The potential effects of climatic changes to natural risks are discussed widely. But, the formulation of strategies for adapting risk management practice to climate changes requires the knowledge about the existing risks – the starting point of a trend. Furthermore, risk management requires the involvement of all relevant stakeholders and the search for the most efficient and the most suitable contribution to risk reduction. The main objective was to elaborate a method for analyzing and comparing natural risks induced by different processes and therefore gaining an overview about a multi-risk situation. This comparative analysis should provide the basis for pointing out the hot spots of natural risk in a region on the municipal level. The method should provide the basis for a controlling system that is observing periodically if the effects of climatic changes do increase the risk situation. With this information, the discussion about potential increases in natural risks due to climatic changes could be made on an objective level.

Furthermore give the case studies an overview of the risk situation within the investigated area, improve the risk assessment on the community level and the risk awareness of policy makers and stakeholders concerning risks from natural hazards.

### *Major findings and specific recommendations*

The factsheets on municipality level summarize and visualize the results of the risk situation in a comprehensible form. The number and units of exposed object categories and the expected damages are values that are used in every day management tasks and routines. In addition, the factsheet is a good tool to start the risk dialogue. However, a homogenous data base is needed, because risk management requires the involvement of all relevant stakeholders.

The elaborated approach of the comparative analysis of the spatial distribution of flood risks on a regional level is suited for pointing out the hot spots in the region. Therefore, the priorities for planning risk reduction measures could be defined.

With the elaborated information basis, a point of origin for setting up an indicator system for monitoring the effects of climatic changes to the multi-risk situation has been created.

## 3.3 | CONCLUSION

### 3.3.1 | GENERAL ADAPTATION STRATEGIES CONCERNING HAZARD MAPPING

As the knowledge about the impact of climate change (CC) on the frequency and intensity of hazardous events is still fragmentary, adaptation strategies on the European level are focused on the reduction of vulnerability of society and infrastructure. In other words, adaptation strategies aim at the improvement of resilience and flexible response to risks caused by natural hazards. European countries put much effort in the examination of ways to improve monitoring of impacts and adaptation measures in order to develop vulnerability indicators. In order to justify additional costs for CC-related measures more quantified information of cost-benefits of adaptation is needed. The EU is therefore strengthening its analysis and early warning systems and integrating climate change into existing tools such as conflict prevention mechanisms and security sector reform. Adaptation to CC will be a long and continuous process. It will operate at all levels and require close coordination with stakeholders. The EU will support international and national adaptation efforts ensuring that there are adequate resources for efficient and cost-effective adaptation action to provide a sustainable and sound economic basis for future generations.

In practice adaptation strategies have two contradictory aspects:

- The general impact of CC on human activities (health, economy, and cultural heritage) and environment is beyond debate while up to now the extent of impact on natural hazard can hardly be proven quantitatively. The “climate signal” is superimposed by great uncertainties in natural hazard process models.
- It is also beyond debate that the impact of the rapid increase of damage potentials due to human activities is of major significance of vulnerability. Thus natural hazards are also a global change (not only climate change) topic and natural catastrophes are – in reality – often social catastrophes.

This leads to the conclusion, that adaptation strategies concerning the hazard maps are urgent, with or without CC. Looking upon the national adaptation strategies a wide range of valuable measures and action can be identified, that provide important links for the implementation of AdaptAlp WP5 results:

- Further improvement of susceptibility, hazard and risk maps
- Sustainable regional development with respect to hazard zoning
- Improvement of web-based information systems (Free public accessibility to hazard information)
- Establishment of susceptibility and hazard maps in the legislation that regulates regional development
- Keep actual and future endangered spaces free (hazard mapping)
- Adaptation of buildings and infrastructure in risk areas (construction standards)
- Integrating scenarios into hazard assessment process
- As values for design events in small catchment areas are highly uncertain, the use of long-lasting data sets is required (inventories).
- Research on the interaction of CC (precipitation, T and air pressure variations) and slope stability.
- Raising public awareness for residual risks.

### 3.3.2 | CONTRIBUTION OF ADAPTALP WP 5 TO THE GENERAL ADAPTATION REQUIREMENTS

The general goal of AdaptAlp WP 5 was the consideration of Climate Change in the assessment, evaluation & harmonization of approaches & methods of hazard mapping applied in the Alpine Space. The transnational improvement of geological & water-related susceptibility and hazard maps, the harmonization of technical terminology & the creation of a basis for cross-sectoral hazard mapping supports essentially the identification of balanced adaptation measures. It also provides input for the implementation of the European Flood and INSPIRE directive & Alpine Convention. Project activities aimed at the reduction of uncertainties by provision of precise data, design events and innovative methods considering climate change for improved modeling and prediction of natural hazards and its impacts in the Alpine space. The project aimed at the improvement of information on impacts of CC esp. on regional level (e.g. high resolution modeling, design events) and the evaluation of different methods of risk assessment, hazard mapping & risk management in the Alpine Space. The activities concentrated on identification of best methods & transferring of best practice experiences into adaptation measures in model regions. Risk reduction by raising the awareness of local stakeholders was a further issue in AdaptAlp WP 5.

In Table 3.4 the specific contributions and conclusions in the major fields of investigation in WP 5 according to the project goals of AdaptAlp are summarized.

PROJECT GOALS OF ADAPT ALP	FIELDS OF INVESTIGATION (TOPICS WP 5)	RECOMMENDATIONS/CONCLUSION
The European Flood Directive other related directives	Linking hazard risk: tools and case studies	Fact sheets help to raise awareness in the communities as they help to start the risk dialogue with a strong link to the European Flood Directive.
The reduction of uncertainties within methods or data	Standardization (harmonization) of terminology concerning geological hazards in Europe	Uncertainties regarding the definition of terms are reduced through the development of a consistent terminology
	Minimum requirements of geological hazards mapping	Uncertainties regarding the definition of terms are reduced through the development of a consistent terminology or an explained terminology so that the different administrative departments understand the meaning of terms in other countries
	Improving dating methods of past events Scenario – based hazard analysis under consideration of climate change	At present, there are no rigorous methods available which would allow determination of event probability of torrential processes. An accurate method for the hazard assessment of torrential processes is the analysis of past events. Unfortunately data on past events is often not available or lacks on satisfying spatial and temporal resolution. By including “silent witnesses” into hazard and risk assessment uncertainties within the assessment can be reduced.
	Scenario – based hazard analysis under consideration of climate change	Addressing explicitly the uncertainties in hazard assessment results in a net benefit for the subsequent risk assessment steps. Providing a structured approach procedural rationality is guaranteed and the reliability of the results is increased.
	Linking hazard risk: tools and case studies	The elaborated method should provide the basis for a controlling system that is observing periodically if the effects of climatic changes do increase the risk situation. With the received information, the discussion about potential increases in natural risks due to climatic changes could be made on an objective level.
INSPIRE/ Improving efficiency of transnational risk management	Standardization (harmonization) of terminology concerning geological hazards in Europe	The multilingual glossary improves the efficiency of transnational risk management by standardizing the terminology for geological hazards
	Minimum requirements	The definition of minimal requirements of hazard mapping constitutes the base for the implementation of landslide susceptibility and hazard maps as a tool of hazard prevention and for the comparability of the results of mapping. The process should be transparent and comprehensible, therefore the maps will be acceptable for decision makers, responsible local administration and potential affected citizens. Because of a lack of minimal requirements and comparability at the time, the laying-down of requirements will influence the future efforts of hazard mapping, research and practice and will facilitate the adaptation of hazard mapping to the challenge of future effects by climate change.



PROJECT GOALS OF ADAPT ALP	FIELDS OF INVESTIGATION (TOPICS WP 5)	RECOMMENDATIONS/CONCLUSION
INSPIRE/ Improving efficiency of transnational risk management	Scenario – based hazard analysis under consideration of climate change	The methodological efforts undertaken in theory and practice by the agencies contributing at various levels to the elaboration of legally binding hazard maps result directly in an increase of efficiency in this core competence field. The principles for a scenario-based hazard assessment provide guidance for addressing specific problems related to hazard assessment and constitute a conceptual bridge to multi-hazard assessment. The wide range of performed case studies provides insights at various levels into the subtleties of hazard assessment in practice.
	Linking hazard risk: tools and case studies	Factsheets will help to make a priority list of necessary protection measures.
Raising awareness and supporting adaptation actions	Improving dating methods of past events	The reconstruction of frequencies and the analyses of climate change impacts on events performed at ten different sites in Austria are examples to illustrate the breadth of contemporary dendrogeomorphology and may assist local authorities in better understanding spatial and temporal changes of debris flows (and snow avalanches).
	Linking hazard risk: tools and case studies	Factsheets help to raise awareness in the communities as they help to start the risk dialogue with a strong link to the European Flood Directive.
	Scenario – based hazard analysis under consideration of climate change	The wide range of performed case studies provides insights at various levels into the subtleties of hazard assessment in practice.
Improving dating methods of past events	Improving dating methods of past events	The handbook for practitioners about “Tracking of past events on fans and cones: dating techniques and applications” improves hazard and risk assessment by including “silent witnesses” into the assessment procedure. The farsighted goal of this study was the provision of reliable methods for event dating in order to enable condensed data sets for accurate prognosis of future catastrophic events.
Derivation of adaptation measures/strategies	Synthesis	Based on the experiences within AdaptAlp and a workshop a factsheet and a publication about hazard mapping adapted to climate change was elaborated

Table 3.4: Contribution of the WP 5 Activities to the main goals of AdaptAlp

### 3.4 | RECOMMENDATIONS FOR ADAPTATION OF HAZARD MAPPING TO CLIMATE CHANGE

#### *Recommendations related to the specific investigations within AdaptAlp WP 5*

1. Implementation of a transnational standard in hazard mapping (mass-movements, water-related hazards) including a harmonized terminology.
2. Improvement of methods for tracking (dating) historic events aiming at the consolidation and expansion of time series (in order to reduce uncertainties in extreme value statistics for DE).
3. Improvement of accuracy of hazard process models and deepening the understanding for the impact of CC on parameters and model behavior.
4. Integrating scenarios into hazard assessment process and definition of DE.
5. Strengthening research on the interaction of CC and slope stability in order to improve accuracy of susceptibility (risk) maps for mass-movements.

#### *General Recommendations for adaptation of hazard mapping*

1. Strengthening of research on natural hazard processes in order to reduce inaccuracies in event data and process models (suppressing the evidence of the “CC-signal”).
2. Area-wide provision and application of detailed hazard maps in Alpine (European) countries (for the reduction of vulnerability/increase of resilience).
3. Assessment of the ratio of impact of climate change versus demographic (socio-economic) change (natural catastrophes = social catastrophes) for adaptation of hazard mapping to the requirements of hazard-proof land-use (sustainable regional development with respect to hazard zones).
4. Improvement of far-sighted methods for monitoring effects of adaptation measures (with special regards to hazard maps) on the impact of CC.
5. Improvement of information on impacts of CC esp. on the regional level (by high resolution hazard modeling and maps).

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# 4. | RISK MANAGEMENT AND RISK PREVENTION

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## 4.1 | INTRODUCTION

It has been possible to observe a fundamental shift in the paradigms for dealing with natural hazards and related risks throughout the Alps over the past decade. The increased complexity of risk situations and the extent of damage, on the one hand, and the limited financial resources, on the other, led to the development of a new approach. There has been a shift in the focus in the area of natural hazards from the defence against natural hazards through the construction of protective measures as the principal solution to risk mitigation to a more holistic approach that views risk management as involving a variety of individual activities. This change in paradigm began in the late 1980s with the implementation of integrated watershed management in different regions of the Alps and was significantly reinforced by the enactment of laws on risk-based land-use planning and guidelines for risk analysis and risk-based decision-making in the planning of protective measures.

Today, the management of natural hazards and risks in an integrated and interdisciplinary way has become a commonly accepted standard in the Alps. Integrated risk management is the process of finding the most efficient solutions and combinations of measures for risk reduction throughout all phases of risk management (prevention, intervention, restoration). However, the implementation of the integrated approach to risk management often falters due to the persistence of traditional ways of working.

The implementation of integrated risk management in practice varies remarkably between Alpine regions. While some regions focus more on prevention, others focus more on the optimisation of intervention-related work. However, all risk-management stakeholders in the Alps are facing challenging trends in the development of natural risks as a result of human development and changes in the climate.

The ‘catastrophic’ events of recent years revealed some weaknesses in risk management practice in the Alps. The challenges involved in improving natural hazard and risk management are manifold. Economic development results in the spread of settlements and infrastructure towards endangered zones. At the same time, the values of houses and goods and mobility requirements are increasing. The functioning of local economies is based on the smooth operation of transport, communications, water and electricity supply infrastructure. This leads to an increased dependency of human activities on the continuous functioning of infrastructure and, therefore, to an increase in vulnerability to the effects of natural hazards. Society’s demand for absolute safety in the area of natural hazards is growing while, at the same time, individual responsibility is increasingly denied. The growing demands for higher safety standards will also put greater pressure on public finances. Furthermore, the intensity and frequency of natural hazards are expected to increase in specific cases due to climate changes.

With or without the effects of climate change on natural hazards, the challenges facing natural hazard and risk management practice are enormous. As these challenges facing risk management practice affect all responsible institutions in the Alpine Space in almost the same way, similar efforts to find solutions to deal with them simultaneously in all regions in the Alps can lead to a waste of time and resources. Some tasks cannot be dealt with by single institutions alone; the challenges can only be faced through cooperation between different actors in different legislative and administrative contexts and on the basis of a common strategy.

The Alpine Space 2000-2006 project “ClimChAlp – Climate change, impacts and adaptation strategies” developed recommendations for improving integrated risk management and for adapting risk management practice to the effects of climate change. According to these recommendations, the exchange of information and experience across administrative borders and disciplines plays a very important role in optimising risk management practice. The ClimChAlp project identified improvements in integrated watershed management, the further promotion of the exchange of knowledge and information, the promotion of the individual responsibility of citizens in relation to natural hazards, the increase in the involvement of the public in the planning of protective measures and the improvement of early warning systems as priorities for the further optimisation of risk management practice.

The activities for Work Package 6 of the AdaptAlp project were defined on the basis of the recommendations formulated in the common strategic paper of the ClimChAlp project. The AdaptAlp project should answer the questions that arose during the ClimChAlp project and follow the recommendations. Hence, the work carried out by WP6 of the AdaptAlp project involves a wide range of activities covering the entire cycle of integrated risk management.

## 4.2 | TAKING CLIMATE CHANGE INTO ACCOUNT IN RISK MANAGEMENT IS A DIFFICULT TASK

A lot of uncertainties and gaps exist in the knowledge regarding the causes and effects of the rise in temperature that started in the last century and continues to the present day, its future development and its effects on the climate. There are significant uncertainties in the emissions scenarios for the next 50 to 100 years, on the one hand, and in the results obtained using global and regional climate models, on the other. This is particularly applicable to the local and seasonal effects on precipitation, its intensity and frequency of occurrence, and its absence.

There is quite high degree of certainty with regard to the fact that the temperature increase due to climate change has already affected and continues to affect the Alpine space. Hence, the impacts of and necessary measures for adaptation to climate change relate to the increase in temperature. As demonstrated by a survey of such examples, adaptation measures for natural hazards resulting from glacier hazards (e.g. glacier lake outburst floods GLOFs) and from permafrost degradation (e.g. accelerated rockfall activities) have already been implemented today. However, these few examples can only be found in the highest regions of the Alps which are most sensitive the increase in temperature.

Whereas the future direct effects of increasing temperature on natural hazards could be assessed as relatively traceable, the effects of climate change on natural hazards relate to extreme precipitation events, are more difficult to assess and are subject to uncertainties. As the existing hydro-meteorological time-series, which also include data on extreme hazard events, do not usually go back much more than 100 years, it is very difficult to predict the probability of occurrence and extent of the damage of possible extreme scenarios with accuracy. If attempts are made to provide a prognosis despite this, they are hampered by varying degrees of uncertainty. The formulation of scenarios with a return period of more than 100 years by means of extreme statistical values is subject to uncertainties. Moreover, the projected scenarios and effects of climate change on extreme natural hazard processes with a low probability of occurrence extend the already existing uncertainties laying in the assessment of seldom events. Due to the topographical diversity of the Alpine region, formulating reliable forecasts is an enormous challenge. Hence, the investment of funds in protective measures that cover the potential effects of changes in the climate is also subject to uncertainty.

The topographic, climatic and geomorphologic diversity of the Alps requires the adoption of a locally differentiated view of the potential effects of climatic change on natural hazards. Some areas are likely to be affected by natural hazards related to changes in the climate and others will not experience changes in the current natural hazard situation. Nonetheless, even if there is a general increase in the frequency and intensity of natural hazards, the process involved in managing the related risks will not change remarkably but it becomes even more important. The risk cycle is applicable to risk management under both current and future climate conditions. The principle behind the establishment of the most suitable and efficient combination of solutions for risk minimization is also valid in case of increasing risks due to the effects of climate change.

Even if the „event“ in this graphic becomes more frequent and more intensive, the principle of integrated risk management remains the same



Figure 4.1: System of risk management (cycle)

The risk resulting from natural hazards is defined as a quantifying function of the probability of occurrence of a hazard process and the related degree of damage. The latter is specified by the damage potential and the vulnerability of the endangered object (UNDP, 2004).

$$R_{i,j} = p_{si} \cdot A_{oj} \cdot p_{oj,si} \cdot v_{oj,si}$$

According to the UNDP (2004) definition, the specifications for the probability of the defined scenario ( $p_{si}$ ), the monetary value of the object affected by this scenario ( $A_{oj}$ ), the probability of exposure of object  $j$  to scenario  $i$  ( $p_{oj,si}$ ), and the vulnerability of object  $j$  in dependence on scenario  $i$  ( $v_{oj,si}$ ) are required for the quantification of risk ( $R_{i,j}$ ).

Apart from the probability of occurrence and the intensity of potential natural hazards what can be increase due to climatic changes also the increasing damages and the increasing vulnerability of endangered objects are influencing the level or risks. In comparison to the potential effects of climate change, the latter parameter of the risk formula affects the resulting risk much more.

With the negative effects of climate change on natural hazards, integrated risk management becomes more important. Hence the improvement of integrated risk management is a crucial requirement for adapting the practice of natural hazard management to the effects of climate change. The following chapter presents the state of the art in the implementation of integrated risk management and identifies the key tasks for improving the practice of integrated risk management.

### 4.3 | INTEGRATED RISK MANAGEMENT - STATE OF IMPLEMENTATION AND KEY POINTS FOR IMPROVEMENT

The WP6 working group evaluated the state of the art in relation to the practical implementation of integrated risk management in their regions. On the basis of these evaluations, the working group identified the following key gaps in the implementation of integrated risk management:

- Integrated risk management is an efficient approach to dealing with natural hazards, including the related risks and the effects of climate change on natural hazards. Improvements are still required with regard to the implementation of integrated risk management in practice.
- Integrated risk management requires the coordination of the activities of all relevant stakeholders in risk management. However, coordination within the risk management process is weak.
- A discrepancy exists between the existing knowledge and the practical application of this knowledge in the spatial planning sector. This discrepancy represents one of the greatest deficits in integrated risk management.
- Knowledge transfer between the relevant stakeholders and between different planning disciplines and the exchange of information is not institutionalized.
- The practical implementation of integrated risk management requires a long-term time horizon. The adoption of short-term changes in risk management policies soon after natural hazard events runs counter to the long-term setting of priorities. Up to now, investments in protective structures have been mainly driven by natural hazard events and not by preventive risk analyses.
- The level of awareness of local stakeholders (decision-makers at community level) of natural hazards is weak.
- The awareness of citizens and private property owners of ways of reducing damage in case of natural hazard events and of their personal responsibility for taking preventive measures to reduce their exposure to risk is weak.
- The assessment of natural hazards and risks is affected by uncertainties; due to either the stochastic character of natural hazards or gaps in the knowledge and understanding of the processes themselves.
- The effects of changes in the climate are generally increasing the uncertainties in natural hazard assessment. The question as to whether and how the potential effects of climate change should be taken into consideration in hazard mapping remains open.

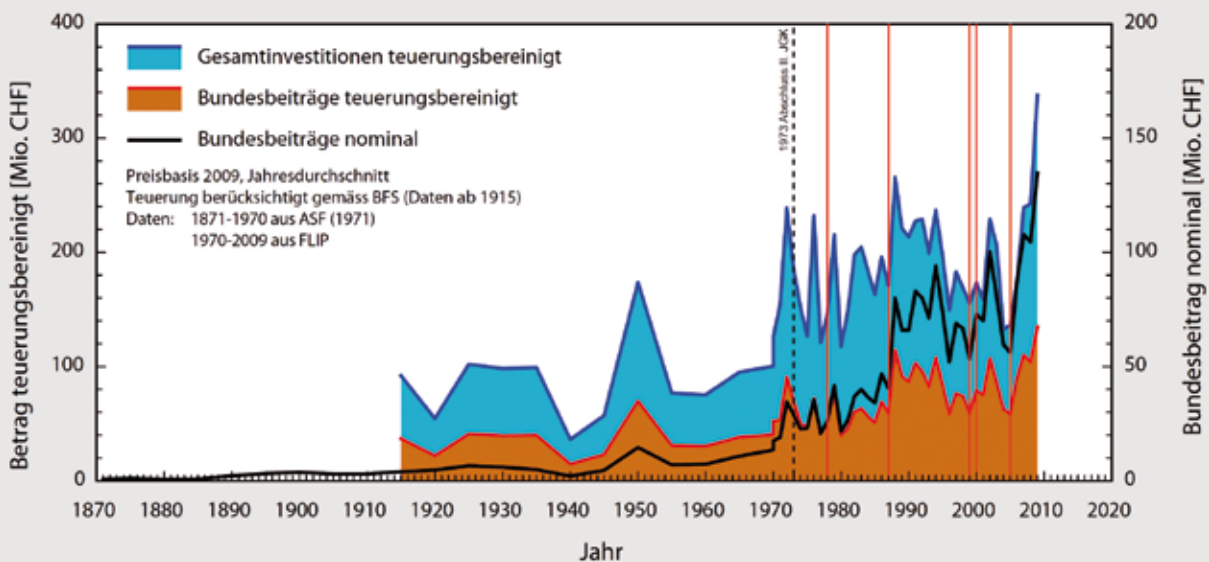


Figure 4.2: Investments in flood protection measures from 1871 to 2009 in Switzerland in relation to flood events with damages. Source: Swiss Federal Office for Environment

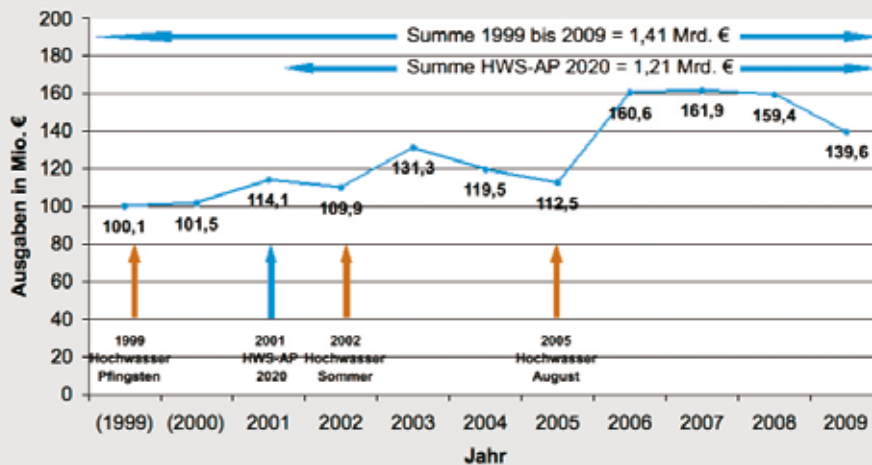


Figure 4.3: Investments in flood protection measures from 1999 to 2009 in Bavaria in relation to flood events with damages. Source: Bavarian State Ministry of the Environment and Public Health

The focus of WP6 of AdaptAlp was on the updating the state of the art in integrated risk management, on risk dialogue at a local level, on education, training and communication, and on the development of new methods for improving risk management. All of the described activities contribute jointly to the improvement of integrated risk management.

A large proportion of investments in safety measures for protection against natural hazards are „triggered“ by hazard events (Figure 4.2 and Figure 4.3). Far more money is still made available for reconstruction after major hazard events than for long-term preventive work. Therefore it is necessary to ensure that risk-appropriate and cost-effective solutions are targeted. Following the approach of integrated risk management based on the risk cycle (Figure 4.1) is supporting a cost-efficient balance between prevention, recovery and reconstruction.



## 4.4 | RISK DIALOGUE AT LOCAL LEVEL

The aim of risk dialogue is to create the basis for risk-appropriate planning and investment decisions based on the best available knowledge and information, including the dialogue with stakeholders. This objective is applicable to both strategic and operative decisions. Land property, infrastructure and real estate, and the public sector are always involved in the protection against natural hazards. In most of the Alpine countries, the municipalities are the institutions with direct responsibility for the safety of citizens. This means that risk dialogue between those who must take responsible decisions, between those affected by natural hazards and between those who have the necessary knowledge and experience is an inevitable necessity. This is the only way that risk-appropriate, priority-based solutions that are also optimized in terms of cost-effectiveness can be established.

The following basic questions must be answered in all risk dialogues:

1. What are the risks?
2. What level of risk is accepted? What are the inevitable risks?
3. What can be done to achieve the targeted level of security?
4. Who is responsible for protection planning, realization and decision making? Are the risks falling into the responsibility of the public or into the responsibility of the individual?
5. What do the corresponding measures cost?
6. Which are the measures with highest priority?
7. What are the limits of protection measures? How do we manage residual risk?

The advantage of the intensive involvement of decision-making authorities is that their awareness is increased and they become participants in the process. This is of particular significance in cases based on knowledge and information characterised by a high degree of uncertainty. The more complex the contexts and the more uncertain the information used to describe the individual hazard processes and their effects, the more holistic and broad-based the risk dialogue must be.

The WP6 working group followed risk dialogue approaches on different levels. The following conclusions may be drawn from these experiences gained within the AdaptAlp project and other projects:

- Factually sound and well-prepared risk dialogue generates transparent and comprehensible decision-making bases. Making existing knowledge and information available and making optimum use of the knowledge available among experts and people with relevant experience are preconditions for successful risk dialogue. The decision-making authority should also be involved in the risk dialogue. This should result in increasing the awareness of politicians and in motivating them to engage in preventive protection work against natural hazards and the management of climate change adaptations. The aim is to encourage politics to become more involved in prevention even if it leads to fewer plaudits than the provision of resources in the case of a disaster.
- The introduction of the risk-dialogue strategy leads to the adaptation of commonly accepted solutions for risk management within a municipality, region or country.
- The risk dialogue provides the basis for a problem-resolution process that begins with the analysis of the problem and ends with the implementation of a measure or combination of measures. The advantage is that it involves participative learning and decision-making processes on an elevated factual level.
- Thanks to risk dialogue it is possible to reduce the time required for the analysis, planning and implementation phase considerably and make cost savings accordingly.
- In the context of holistic and sustainable development, risk dialogue offers the only way of dealing with the influences of climate change in a factual and risk-appropriate way by forming plausible scenarios and shaping the future.
- The implementation and management of risk dialogue requires corresponding training which is currently not available.
- Those who participate in risk dialogue must understand risk management methods so that they can evaluate and assess the results that arise from the risk dialogue in terms of their significance and relevance.
- Risk dialogue is the most effective way of reaching people who are exposed to natural hazards and of increasing their awareness and personal responsibility for reducing their vulnerability to risk.

Instruments like risk dialogue, in particular, and participative planning processes, in general, should become a minimum standard for further Alpine Space projects dealing with climate change and natural processes and their effects on people.

## 4.5 | COORDINATION, COMMUNICATION AND EDUCATION

The practice of integrated risk management requires the interconnected and coordinated effort of many actors and institutions. Integrated risk management is a task to be carried out at trans-national, national, regional and local administrative level. Therefore, natural hazard risk management requires the collaboration and coordination of a number of stakeholders on different administrative levels. All responsibilities and actions must be coordinated and must complement each other. The effect and cost-effectiveness of risk-appropriate measures can be considerably increased by the exploitation of the synergy potential between the institutions involved in the risk cycle. The declared aim must be to make optimum use of knowledge, experience and existing data.

The precondition and basis for the efficient coordination of activities of all relevant actors are risk communication and risk dialogue. Without these, the advantages that are offered by integrated risk management cannot be exploited. Therefore, risk communication and risk dialogue must be promoted and appropriate training in these methods must be provided.

Some minimal requirements must be fulfilled to achieve more intensive cooperation between the different stakeholders and disciplines involved in integrated natural hazard risk management:

- The stakeholders involved must be willing to collaborate with others (other disciplines, other administrative responsibilities).
- All stakeholders should have a common understanding of the goals and methods of integrated risk management. Therefore the common goal of establishing a certain safety-level for the public through the implementation of the most efficient measures should be given a higher priority than the goals of the individual institutions.
- All stakeholders should use a common “language” in terms of using the same technical terms and meanings.

These requirements can only be fulfilled through the education and training of all of the stakeholders. The basis for education and training is communication. Risk communication or risk dialogue could form part of interrelations between administrations and the public, between experts and students, between natural hazard experts and fire-fighters and between all involved persons.

All of the WP6 activities regarding risk communication and training are summarised in these topics: the different possibilities for the exchange of experience, the educational activities, tools for implementing risk communication, including the testing of video conferencing techniques.

First, the project partners involved in WP6 tested different ways of improving risk communication between members of a transnational working group. Following the successful establishment of the working group during the ClimChAlp project, the working group consolidated the collaboration by increasing the frequency of its meetings. A greater number of meetings meant more time was required and travel costs generated in attending such meetings. Travelling around the Alps for meetings also has an impact on climate warming due to the emissions of CO<sub>2</sub> generated. To minimise the climate impact and the travel time and costs involved, the working group tested different video conferencing techniques. After some technical difficulties and some training in the use of video conferencing technologies, the members of the working group were able to use this information and communication (ICT) technique successfully for the purpose of the work package.

Video conferencing techniques are also frequently used by risk management teams whose members are located in different places, especially during natural hazard events. More than other meetings, video conferences require more sophisticated management on the part of the session leader. In summary, video conferences work well if the team is already set up and its members are familiar with modern ICT tools. Video conferences are not suitable for educational purposes and for meetings with a strong link to a specific location, e.g. a village where flood protection measures have to be planned and constructed.

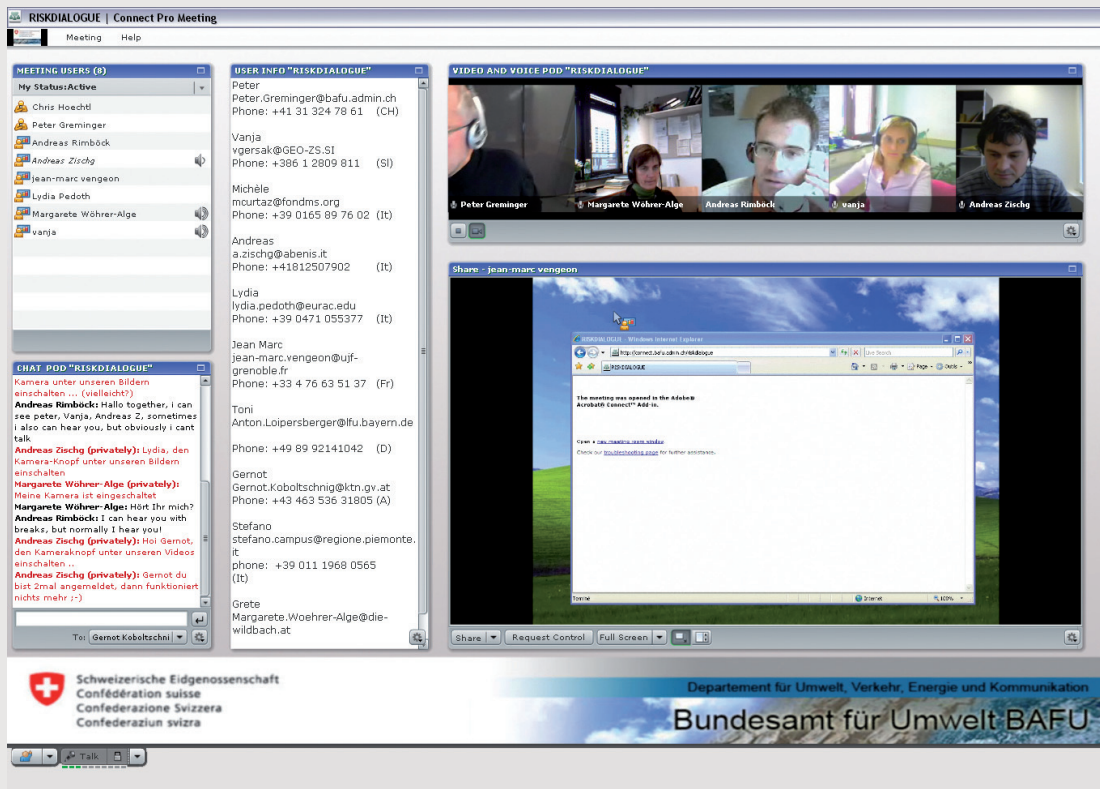


Fig. 4.4: Screenshot of a video conference meeting of the working group of WP6. New electronic communication tools are reducing travelling time and costs.

The best instrument for the latter purpose – i.e. the search for the most suitable and efficient preventive measure through a discussion between experts from different disciplines – is the expert workshop. The working group organized some expert workshops and evaluated their results from the perspective of risk communication. Interdisciplinary expert workshops held at an early stage in the process for the planning of natural hazard prevention and involving experts from different regions are very helpful for the discussion of complex situations and finding innovative solutions to the specific local problem. A group of experts from different backgrounds and different disciplines brings more specific perspectives to the problem than a single institution can. Therefore, the number of potential solutions to be evaluated for selection is much higher. This leads to a convergence of the selected solution for a risk situation towards the (unknown) best solution.



Figure 4.5: Interdisciplinary expert workshop in Immenstadt 2010 „Risk management in alpine torrents and rivers – Riskplan“. (Picture: Marion Damm)

Interdisciplinary workshops are also suitable for coordination between research institutes and practice. Workshops held for this purpose are organised in form of expert hearings. The experts from practice (stakeholders, administrations) ask the scientific experts specific questions. Expert hearings offer a pragmatic way of transferring up-to-date knowledge from science to practice, particularly when the scientific knowledge has not been consolidated and is subject to uncertainties or ongoing evolution (as is typically the case in the assessment of the consequences of climate change). Apart from expert hearings, the associations of practitioners are also important for the dissemination of new scientific findings on climate research. In most cases, these associations have their own information channels (e.g. newsletters or publication series) that could be used to strengthen the direct transfer of new and important scientific findings to practice.

These circumstances underline the importance of education in risk management. The dissemination of methodologies and practices to students (and practitioners) is important for the improvement of risk governance in the long-term. During the AdaptAlp project, a workshop was organised between experts of the local and regional administrations responsible for natural hazard management and students. Concepts for protective measures in a community were jointly evaluated at the workshop. Local decision-makers and emergency personnel (e.g. mayors, fire fighters, etc.) are the responsible on-site and have to react promptly and correctly in case of a natural disaster. To fulfil these ambitious requirements a consolidated knowledge about natural hazards and risk management is required. As a training material and as a reference book for non-experts in natural hazards management a handbook of natural hazards was compiled. As it is generally intelligible it could also be used for rising awareness in senior classes of schools.



Figure 4.6: Handbook of natural hazards for practitioners and students. (AdaptAlp website → Practitioners' corner)

Risk-based decision making also requires training. Setting priorities for risk reduction measures on the basis of risk analyses requires evaluating the most efficient use of the available funds for risk prevention. The pilot studies carried out within the framework of AdaptAlp revealed that the software program RiskPlan is a valuable tool for training risk-based decision-making. RiskPlan enables the evaluation of the costs and benefits of a variety of different approaches to risk reduction in a specific situation. The most efficient combination of measures within a set of possible risk reduction measures can be identified using this tool. It supports expert workshops and also supports risk dialogue. The results of risk analyses and the result of cost-benefit analyses can be presented shown in the form of simple graphics. The experiences of the project partners in using risk plan showed that RiskPlan is suitable for most of the purposes described in this and in the previous chapters. The tool is available on the website (see Figure 4.7).

The exchange of experience works well on the basis of best practice examples. By means of the exchange of these examples, knowledge about integrated risk management or a specific topic could easily be transferred from one stakeholder to another who is seeking solutions to similar problems. Good practice examples have a clear advantage over all other risk communication methods: they describe solutions that have been implemented and can be evaluated on the basis of facts.





Figure 4.7: Screenshot of a web-based tool for risk analysis RiskPlan ([www.riskplan.admin.ch](http://www.riskplan.admin.ch))

Another possibility for bridging knowledge gaps (particularly regarding the effects of climate changes or methodologies for implementing integrated risk management) is the exchange of practitioners between institutions, especially between administrations responsible for natural hazards and risk management. While some institutions are specialised in preventive measures, others are specialised in risk analysis or intervention measures. Temporary visits and internships by individuals from different institutions support the exchange of specific knowledge. During the AdaptAlp project, a tool was created for this purpose. A platform for supporting the exchange of practitioners between institutions was developed.

The exchange platform “on\_alp\_exchange” is located on the INTERPRAEVENT and AdaptAlp website ([www.interpraevent.at](http://www.interpraevent.at) → service → on\_alp\_exchange; [www.adaptalp.org](http://www.adaptalp.org) → Links) and was tested by the working group. The platform is well suited for this purpose, but however intensive promotion is needed.

Last but not least, two conclusions could be drawn from all of the activities mentioned here.

1. The coordination of all stakeholders in integrated risk management and risk communication requires a person/institution who/that works continuously on the promotion and organisation of the process and assumes the role of a facilitator, who/which identifies synergies and focuses on making rigorous use of the synergies offered by collaboration. A specific job description or position of this kind does not usually exist and the role must be fulfilled voluntarily. Furthermore, depending on the type of target group involved, the communication process must be adapted to the requirements in terms of technical knowledge, appropriate language and jargon, definitions of terms, and type of dialogue. The information provided to all participants must be complete, comprehensible and organised. The professional skills required for this role of a risk manager are not related to a specific kind of natural hazard process and corresponding specialised training should be provided.
2. The cooperation between the different regions of the Alps leads to a range of added values. A valuable stock of experience exists in the Alpine area – in form of both best practice examples and in-depth experience. All stakeholders follow the holistic approach of integrated risk management. Stakeholders in the Alpine regions are sometimes specialised in different tasks. The systematic combination of the variety of existing approaches and specific expertise about natural hazards and risk management available in the Alpine Space creates an immense and useful toolbox of methods for facing the challenges that arise in everyday practice. Knowledge transfer between the different specialisations of the Alpine regions plays a key role in adapting risk management practice to the effects of climate change (see Figure 4.8). The variety of approaches in the Alps and transnational collaboration forms a flexible network for responding to the challenges of risk management practice.



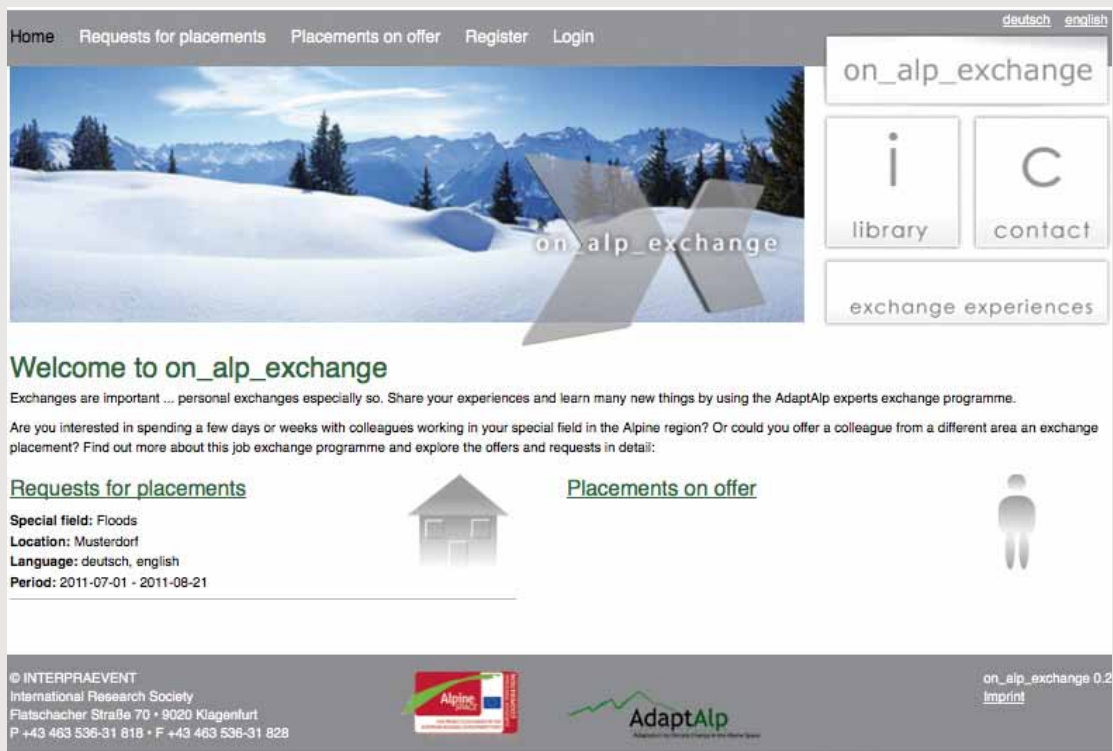


Figure 4.8: Screenshot of the “platform for the ex-change of practitioners”. Supporting the cross border exchange of experiences and knowledge on a practical level ([www.interpraevent.at](http://www.interpraevent.at))

## 4.6 | NEW METHODS FOR IMPROVING RISK MANAGEMENT

In addition to all of the risk prevention activities, intervention shortly before and during the course of flood events is also an important task of integrated natural hazard risk management. Intervention measures also contribute to the improvement of risk management practice. The precondition for the preparation of intervention measures, such as the installation of mobile flood protection measures, the evacuation of houses or the deployment of fire-fighters, is an early warning system that describes the most plausible scenarios. One of the working group’s project partners developed and tested a forecasting model for floods and debris flows. This tool analyses the actual environmental situation and the forecasted weather situation and compares it with historical situations. On the basis of this comparison, the tool calculates the probability of a flood or debris flow event. Hence this tool could reduce the uncertainties associated with the assessment of the consequences of a weather forecast and improve the quality of the forecasts of natural hazard events.

Decisions in the context of integrated risk management are ideally based on the results of risk analyses or cost-benefit analyses. Therefore, the results of risk analyses must be understandable and accessible, especially to the general public. Whereas risk analysis is suited for selecting the most efficient risk reduction measures on a local scale, the comparison of risks, e.g. annual fatality risks or monetary risks, is an instrument for setting the action priorities in the area of risk reduction on a broader (e.g. regional or national) scale. One activity of this work package was the development of a tool for informing the general public about the natural hazard risks in their community and for the comparison of the risks in all communities of a region. The development of a tool for the visualization of the actual risk situation (Figure 4.9) at municipal level provides the basis for the visualization and the dissemination of the results of the preliminary assessment of natural hazards required by the European Flood Directive. This tool shows the potential damages and risks for each community in form of a clear fact sheet and can be accessed on a website. This provides the basis for promoting risk communication in this region.

# Hazard profile municipality of Dellach / Drau, Austria

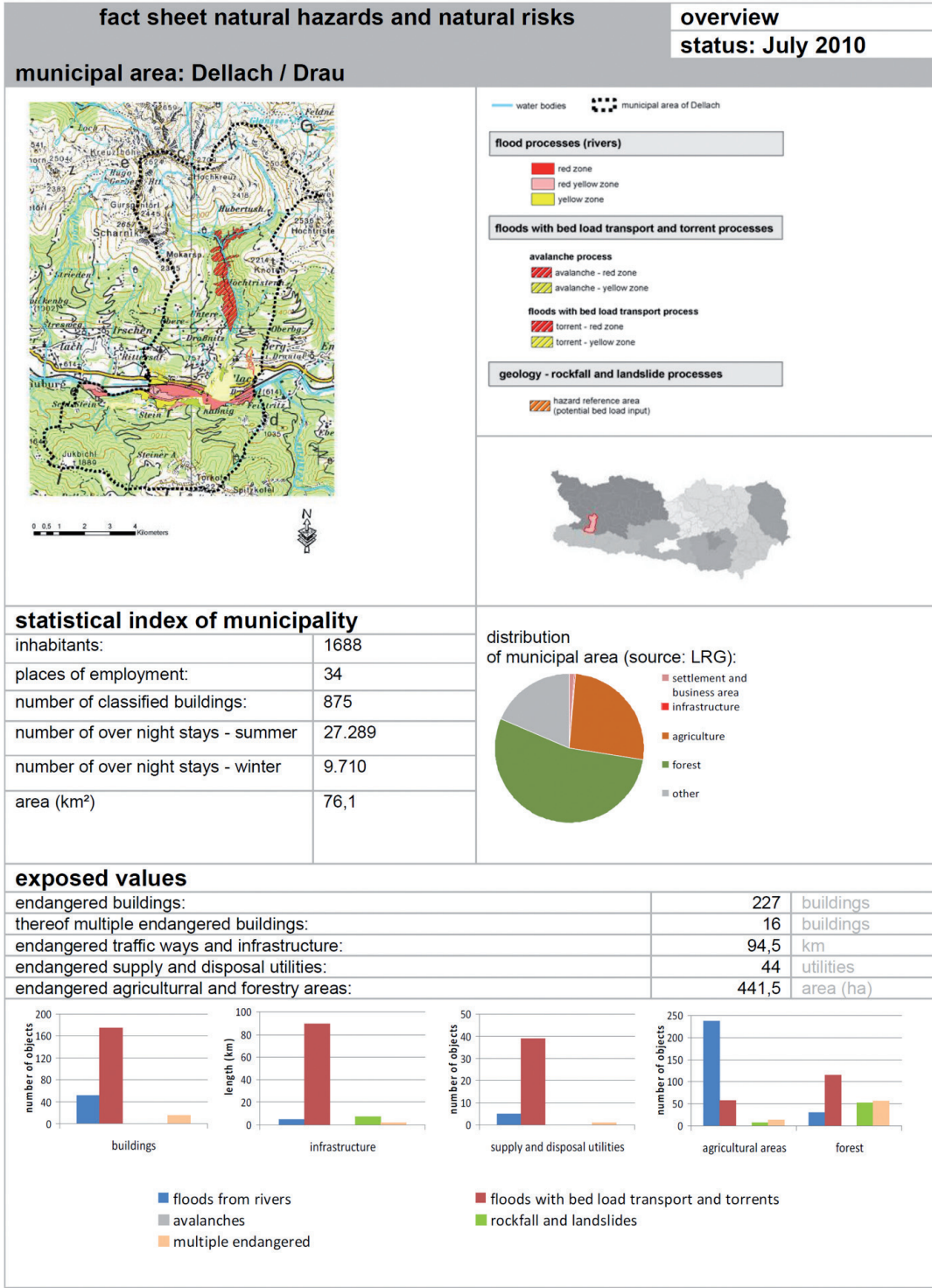


Figure 4.9: Example of one factsheet of natural hazard risks in a community of Carinthia.

## 4.7 | CONCLUSION AND RECOMMENDATIONS

The coordinated activities of the project partners of AdaptAlp within WP6 led to the following conclusions and recommendations regarding the topics of interest described in the introduction.

The holistic approach of integrated risk management offers the only way of dealing with complex situations (which most risk situations are by their very nature). Integrated risk management is currently widely and successfully implemented in practice. However, it requires ongoing improvement.

First, the coordination of all relevant stakeholders involved in integrated risk management must be improved. The coordination of different activities in risk management must be institutionalized and intensified. Without this, the added value of integrated risk management – benefiting from synergies arising from the coordinated actions of different planning sectors – could not be generated. It is recommended that a specific institution, organization or a person be nominated for each process of integrated risk management which/who can facilitate the coordination of all activities in the risk cycle and acts as a platform or a channel for risk communication.

The improvement of the coordination of the activities of all relevant stakeholders requires the intensification of risk communication and risk dialogue. Risk dialogue is the only way that all of the relevant stakeholders in risk management and the affected populations can be involved. It is also the most effective way of raising the awareness and the sensitivity of people exposed to natural hazards of their personal responsibility for reducing their vulnerability. The implementation of risk dialogue contributes to the qualitative improvement of preventive work. The implementation of risk dialogue leads, via an iterative, pragmatic resolution process, to risk-appropriate investments in protective measures which are classified on the basis of cost-effectiveness and priorities.

Because a large proportion of the investments in safety measures for protection against natural hazards are “triggered” by hazard events, it is recommended that a risk dialogue is also held in the case of reconstruction activities after extreme hazard events to ensure that risk-appropriate and cost-effective solutions are targeted. Far more money is still made available for reconstruction after major hazard events than for long-term preventive work. Thus an expedient approach could be to earmark a small amount of around 5–15% of damage remediation funds for long-term preventive measures and for river renaturalization.

A discrepancy exists between the available knowledge and the practical application of this knowledge in the planning sector. This discrepancy could be minimized through the exchange of knowledge and information between relevant stakeholders and through knowledge transfer between different planning disciplines. The exchange of information between all actions in the risk cycle must be institutionalized. Knowledge transfer could be supported by the exchange of good practice examples, by expert hearings, by interdisciplinary expert workshop at local level and by the temporary exchange of practitioners between institutions. The transboundary exchange of experience through individual exchange visits by experts actively involved in practice is worthy of promotion and financing. “on alp\_exchange” is an effective instrument that should be used for this purpose. Many organisational framework conditions of the institutions in the different Alpine countries are currently not suitable for promoting a motivating incentive system for the exchange of practitioners. Because good examples of risk-appropriate actions are easy to understand, it is recommended that the existing collection of good examples of risk management activities and good examples for risk dialogue get further developed for the countries of the Alpine region.

Risk-based decision-making is not a standard process in all regions in the Alps. The availability of a methodology that enables the implementation of the analysis of risks, measures and cost-effectiveness based on scenario assumptions is very helpful. Therefore, the use of instruments supporting risk analysis and cost-benefit analyses for risk-based decision-making is highly recommended. One of these tools is RiskPlan. It supports risk-based decision-making, risk dialogue and the education of practitioners in risk-based decision-making.

In many cases, municipalities do not have the necessary expert knowledge and capacities to provide their population with existential security in all areas and hence are increasingly reliant on the superior authorities and their services. For this reason, it is recommended that the understanding of the distribution of roles and tasks between municipalities, regions etc. is continuously adapted to current safety requirements. Local administrations must be supported by risk managers from regional institutions or by experts. The option of risk management, which involves a risk portfolio (all kind of relevant risks) at municipal, administrative and state level, is basically regarded as a promising way to dealing with all risks.

The cornerstones of the maintenance and improvement of the current level of safety under changing framework conditions are:

- the further development and implementation of integrated risk management
- the promotion of the risk dialogue
- the consistent involvement of all relevant actors and the population in risk management

The current level of safety is continuously changing as a result of the rise in damage potential, the growing vulnerability of endangered infrastructure, the increasing demand for safety and the effects of climate change on natural hazards. Climate change is just one element of the changing conditions in the context of risk management. The continuous improvement of integrated risk management also serves in the adaptation of natural hazards and risk management to the effects of climate changes.

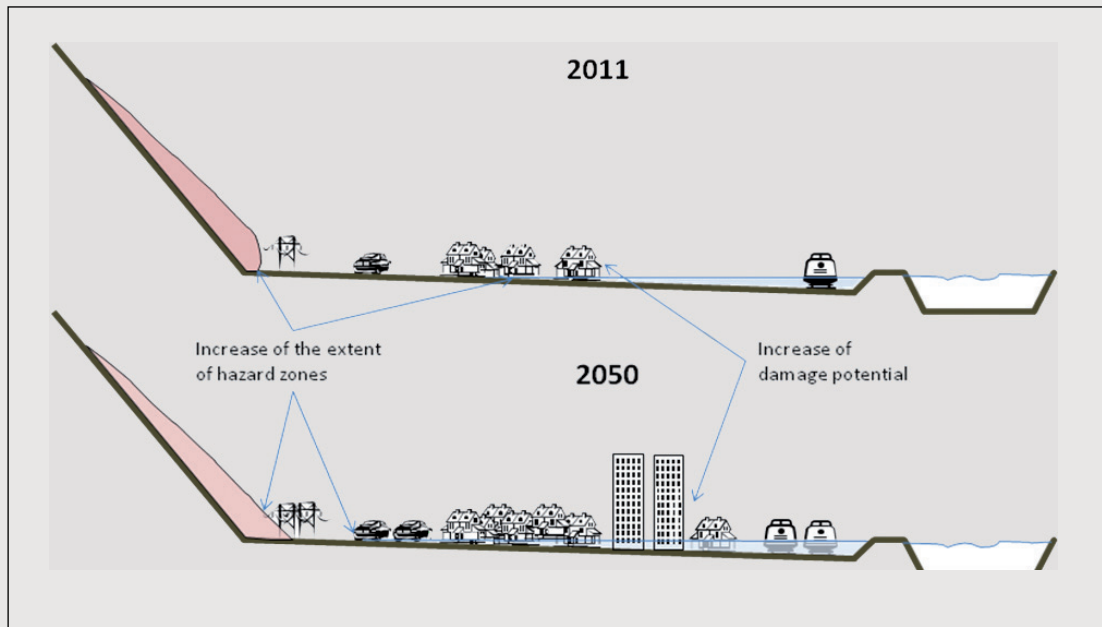
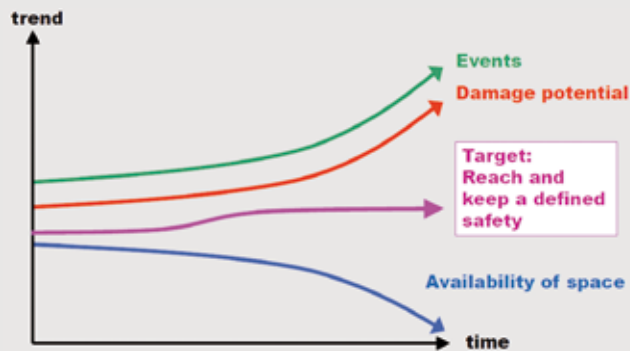


Figure 4.10: Example of the development of the village Garmisch-Partenkirchen from 1861 to 1988. The main goal of integrated risk management within a changing environment is to maintain the targeted level of security. The actual trend shows in many regions increasing damage potential.



The effects of climatic change on natural hazards could increase the hazard potential in some situations whereas, in other cases, they also could lead to a decrease in hazard potential. An update of the existing hazard maps is only necessary if the effects of climate change have a notable influence on the hazard process.

Based on the current state of knowledge, it is recommended that the effects of climate change on natural hazards only be considered if the data relating to them are reliable and significant. It is recommended that the general application of some individual effects of climate change to all natural hazards throughout the Alps be avoided.

This requires the following actions

1. Development of a method for the identification of climate-sensitive areas in which the effects of climate change have significant negative influences on natural hazards.
2. The establishment of a monitoring system for observing the temporal evolution of natural risks in connection with climate data and the development of damage potential. Natural hazard risk analyses must be repeated every 10-15 years. The periodic monitoring of the risks allows the identification of situations in which the effects of climate change have a significant influence on the risks and the targeted level of security decreases as a result. It also makes it possible to distinguish between increasing risks due to climate change and due to increased vulnerability or inadequate land-use.
3. If the risk observation indicates a remarkable increase in natural risks due to the effects of climate change, the risks should be managed through the adoption of the holistic approach of integrated risk management.

Irrespective of climate change we must make a greater effort than hitherto to carry out the work necessary to reduce the risks arising from natural hazards or at least limit them.

In this sense, integrated risk management offers the appropriate approach for dealing with risks induced by the effects of climate change. The instruments of integrated risk management presented in this report are suited for solving all of the highlighted problems of risk management and hence also for the adaptation of risk management practice to the consequences of climate change.

The most effective strategy in dealing with the influence of climate change on natural hazard processes is the appropriate consideration of natural hazard processes in land-use planning, the reinforcement of personal responsibility for the protection of property and risk-appropriate priority-based investment in all kinds of risk reduction measures such as early warning, prevention, emergency planning etc. This necessitates the efficient coordination of the activities and measures carried out by all participating actors and the targeted introduction of a risk dialogue to enable joint and risk-appropriate decision-making, even in uncertain data situations or an observed increase in risks due to climate change.

## 4.8 | FOLLOW-UP OF ACTIVITIES

AdaptAlp identified new approaches and tools for improving integrated natural hazard risk management. The approaches presented in this report only represent a selection of all of the measures that exist for improving risk management and risk governance. However, they have been evaluated as suitable and efficient. Therefore, the working group recommends the use and further optimisation of the described approaches. Hence the following activities, in particular, will be carried out following the completion of the AdaptAlp project:

- Risk dialogue and risk communication will be further promoted in all of the participating countries.
- The handbook on natural hazard management will be disseminated in Austria and continuously updated.
- The cost/benefit analysis method will be further applied and promoted in France.
- The results of the risk analyses at municipality level in Carinthia will be presented and discussed.
- The existing networks of practitioners and scientists will continue to be used for the exchange of knowledge and improvement of integrated risk management.
- The improvement in risk management will be subject to periodic evaluation.
- The integration of natural hazard management and integrated risk management into sustainable development and into the management of the increasing complexity of the society will be further promoted.



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## 4.10 | REFERENCES AND FURTHER READING

### REFERENCES

UNDP, 2004: A global report; Reducing disaster risk a challenge for development.

### WP6 REPORTS

Further information can be found in the detailed reports compiled within Work Package 6 of the AdaptAlp project.

The reports can be downloaded from the project website [www.adaptalp.org](http://www.adaptalp.org) -> Technical Report -> WP6.

- Report on the practitioner's workshop in Immenstadt (StMUG)
- Feedback on RiskPlan workshop (RAVA)
- Report on the exchange of practitioners between GeoZS and BMLFUW
- Report of risk management practice in Bavaria (StMUG)
- Report of the use of RiskPlan at university level for education purposes
- Report on the Nidwalden case study (FOEN)
- Report on the workshop about GLOF hazards (PGRN)
- Book article „Transnational collaboration in natural hazards and risk management in the Alpine Space“ (EURAC)
- Handbook for the use of video conferences in risk communication (EURAC; PGRN; FOEN)
- Report “Assessment of methods and tools for risk management in Bavaria and derivation of recommendations for optimisation” (StMUG)
- Expert Hearing Report “Torrential Risk Management and Environment - Munich, November 05/06, 2009” (StMUG)
- Report Possibilities of adaptation to Climate Change in Slovenia – collecting examples of best practice” (GeoZS)
- Report on a round table „Climate changes in the light of risk management and natural hazards“ (GeoZS)
- Webpage WhoDoesWhat: interactive description of how integrated risk management works all along the risk management cycle concerning Floods, Avalanches, and Mass movements in different regions (PGRN, GeoZS, RAVA, EURAC)
- Report “Certainty and Accuracy Analysis of Design Events with Respect to Gravitative Natural Hazards and Derivation of Climate Change Adaptation Strategies“ (BMLFUW)
- Report „Examples of Climate Change Adaptation and Mitigation in Geo-hazards Risk Management in the Alps“ (BWV)
- Fact sheets for the visualisation of risk for pilot-communities in Carinthia (BWV)
- Software with report containing a description of the tool for the elaboration of comparative risk assessments, a guideline how to use the tool and an evaluation of the tool (BWV)



# 5. | PILOT ACTIVITIES

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Planung

Wasser

Planung  
sicherung v.  
ressourcen)

⊕ Hoge, Starkregen,  
Muren  
← SCHUTZ  
Problem: Landw. / allgemein

⊖ Trockenheit  
SPEICHERUNG  
TECHNOLOGIE (Tropf)  
Problem: Landw.

no durch  
derun



## 5.1 | BACKGROUND

By implementing adaptation activities on local and regional level, the project aims at supporting political and local stakeholders to strengthen adaptation to climate change throughout the Alpine arch. In three different pilot regions – Großes Walsertal (A), Oberallgäu (GER) and Gasen/Haslau (A) – a variety of activities took place with the overall goal to learn about risk awareness in communities and regions and their coping and adaptation strategies. Moreover, the activities in the selected pilot regions aimed at enhancing the acceptance of climate risks and to provide information and guidance about land efficient sustainable development of alpine valleys and a climate adaptive municipal development.

Results and findings from all Work Packages were integrated in the activities of the Pilot Regions to transfer the gained know-how into local and regional land use planning processes. The transnational cooperation of the AdaptAlp project facilitated the information exchange between the different regions from Slovenia to France and contributed to the organization and implementation of activities.



Figure 5.1: Location of the three AdaptAlp pilot areas within the Alpine Space.

During their work the project partners faced various challenges. For instance, they had to overcome information gaps between administration, science and local stakeholders and initiate a dialogue between the different parties and gain the municipalities' interest for climate change issues.

This chapter describes the experiences made and the findings derived from the extensive work in the pilot regions. The conclusions drawn from those findings are a crucial part of the overall AdaptAlp synthesis and the Common Strategic Paper (CSP).



## 5.2 | DESCRIPTION OF PILOT ACTIVITIES

### 5.2.1 | GROSSES WALSERTAL, AUSTRIA

#### *Site information*

The Großes Walsertal, located in the province of Vorarlberg, Austria, was chosen as a test region. A catastrophic avalanche devastated this region in the winter of 1954. This experience not only highlighted the dangers of living in such exposed areas, but threatened the entire livelihood of the local residents. Some 50 years after this event, this region now represents an enduring, developing and attractive living destination with a high standard of safety in the face of natural hazards in the most extreme of situations. For this reason, the Großes Walsertal is especially well suited as a test region for adaptation strategies in regional development after extreme events.

#### *Description of activities*

First, historic catastrophes in Austria were systematically documented and the knowledge of historic catastrophes was prepared for decision makers, affected people, interested laypersons, etc. The idea behind this activity was to show the importance of systematic documentation involving the local population and to use the knowledge of well documented catastrophes as a basis for steering a sustainable area development in an alpine valley (in the sense of risk awareness). Thus, crucial information for development policy and land use planning can be identified. Secondly, the valley of the Großes Walsertal was used as a test site within the 2-semester course 'Integral natural hazard management' in the master level program 'Regional Planning and Development' at the Technical University of Vienna. The students investigated the most important spatial/land use factors (settlement development, energy efficiency, tourism, and agriculture/forestry) in order to anticipate and prepare for the potential challenges that climate change will bring in these areas. At a workshop on July 29th, 2010 the results were presented to local decision-makers.

#### *Objectives*

The objective of this pilot activity was to (1) document and analyze the development of land use and land use planning in an alpine valley in Austria taking climate change into account and (2) raise the awareness of the local stakeholders to the risks and need of adaptation in a changing climate. (3) Moreover, it was the aim to derive recommendations for a climate-sensitive municipal development for Alpine Space municipalities.

#### *Major findings and recommendations*

1. Given that the frequency and power of destruction of natural hazard processes are very high relative to other areas, the Großes Walsertal serves as a “good practice” example for natural hazard management, as well as awareness around personal responsibility.  
→ This awareness or “consciousness” must be maintained and passed on to future generations.
2. The combination of different measures like land use restrictions, reduction of exposure to natural hazards, the maintenance of retention areas and the set up of technical protection measures has created a high level of security in the valley.
3. There is a strong identification of the inhabitants with their valley.
4. An existence in this relatively economically weak region would not be possible without mobility.  
→ With the motto “compromise, organize, and make safe”, commuting can be facilitated by means of e.g. group taxis, a ride-share association and/or an expansion of the provincial public transport.
5. With the foundation of the “Biosphere Park 1990”, the valley made an obligation to the protection of biological diversity, the pursuit of economic and social development and the conservation of cultural aspects. The development of such a park necessitates that decision-makers from each community set common goals and maintain good communication, an aspect that has noticeably improved since the establishment of the park.
6. The valley has reached a high level of economic and social growth. Nowadays, the development seems to stagnate though.  
→ Thus future development should focus mainly on sustainable strategies and maintain the efficiency of existing protection system. This policy will contribute to a good regional adaptation to potential environmental changes as a result of a changing climate.
7. Restricting permanent settlement land is an important tactic for natural hazard management. The denser the protection area, the more manageable are the financial costs of protection measure constructions (i.e. a scattered settlement structure incurs the greatest construction costs).

### Conclusion

The pilot study Großes Walsertal highlighted the absolutely critical role that the protection measures play in the life of the region. Their importance in practice and in the mentality of the people stems largely from the avalanche catastrophe in 1954 which demolished the people's existence in the valley. What can be retrospectively seen as a positive outcome today, this catastrophe initiated a very real awareness of the risks of natural hazards and the need to take personal responsibility for safety. Today the Großes Walsertal is a 'good example' of hazard awareness and disaster preparedness.

The field work was conducted by students of the master course 'Regional Development and Planning'. The intensive work in the Großes Walsertal was a great opportunity for the future spatial planners to learn in the field about the challenges that inhabitants, disaster managers, and decision-makers of Alpine valleys have to face.

Future research should try to find strategies if and how settlement in alpine valleys, highly exposed to natural hazards, is possible under consideration of decreasing financial support and an increasing frequency of natural hazards.

Please find more information on [www.adaptalp.org](http://www.adaptalp.org) → Technical Report → WP 7 → Topic 1

- Report of Workshop in Großes Walsertal (German)
- Summary of Workshop in Großes Walsertal (English)
- Student Report 1 (German)
- Student Report 2 (German)

## 5.2.2 | GASEN AND HASLAU, AUSTRIA

### Site information

During the night between 21st and 22nd August 2005 exceptional rainfall (up to 210mm/36h) triggered more than 500 landslides of different size in the area of the two communities 'Gasen' and 'Haslau' (Eastern Styria, Austria). These landslides caused high economic losses as well as two fatalities. The two communities count about 1131 residents. A thorough documentation of this exceptional devastating event was conducted in the aftermath. This and the extremely high exposure to natural hazards is the reason why it is crucial to establish a sustainable and effective risk management in this region.



*Figure 5.2: In and around the Communities of Gasen and Haslau about 400 predominantly shallow landslides were documented occurring during and shortly after the precipitation event of August 20 and 21, 2005 (adapted from Hagen and Andress, 2009).*

### *Description of activities*

Within hazard zone maps avalanche and torrential hazards are detailed described and subdivided in red and yellow zones; however, geological hazards are only marked as brown reference areas. Precise outline of the boundaries and intensity of the hazards as well as utilization restrictions have to be described within additional experts report.

Catastrophic events like the landslides in Styria in 2005 showed the deficits for planning and realization of mitigation measures, when geological hazards are not precisely outlined and when there is no differentiation of arable and not-arable areas. Therefore a new way of dealing with this problem was tried during the revision of the hazard zone maps in the municipalities Gasen and Haslau. More detailed hazard maps and additional hazard analyses were developed and subsequently discussed with experts and local authorities. Thus, mid and long term problems could be addressed, in particular with regard to land use planning. To also reach children and raise awareness of hazards, risks and adaptation a special workshop was held using special tools and information material.

### *Objectives*

The major aim of conducting an activity in Gasen and Haslau was to facilitate and enhance integrated risk management in these two municipalities. Hazard mapping and spatial planners have to consider implications of a changing climate. Therefore, the development of scenarios and the provision of additional information is an important asset. Furthermore, certain structures for sustainable and effective risk communication have to be established. Altogether the objectives can be summarized as follows:

- Applying geological hazard assessment and mapping in a rural community
- Starting risk communication process
- Supporting adaptation of land use planning to the outlined hazard zones
- Evaluating implementation processes of risk management on community level
- Raising awareness of local people to the necessity of adaptation to the impacts of CC

### *Major findings and recommendations*

- Risk communication has to involve all relevant people: local authorities, experts, researchers and especially affected citizens
- Risk communication should include children and young people. Appropriate material and concepts need to be suitable for children to be able to reach them.
- Successful risk management needs detailed risk communication and people aware of hazards and risks otherwise adaptation will fail or cause unnecessary loss of time and money

### *Conclusion*

Gasen and Haslau is a good practice example for documentation and coming to terms with their history of natural hazards. Detailed hazard zone plans have been developed which form the basis for land use decisions and spatial planning. However, it is inevitable to additionally take into account the changes that might occur with regard to intensity and frequency of natural hazards e.g. landslides in a changing climate. The rise of temperature cannot be neglected and hazard zone mapping in Austria as well as disaster risk management needs to consider the consequences. Developing scenarios is one way to deal with the uncertainties of climate change. Moreover, it is the establishment of an efficient risk communication network and management that facilitates awareness raising and the implementation of adaptation measures. Risk communication should start already at schools including children in the awareness raising process. Only at this early stage, the population can be reached sustainably.

Please find more information on [www.adaptalp.org](http://www.adaptalp.org) → Technical Report → WP 7 → Action 7.2

- Report on results of risk communication, risk management and children workshop
- Biber Berti: Website and material for climate change and natural hazards

## 5.2.3 | OBERALLGÄU, GERMANY

### *Site information*

The Oberallgäu is a region in Bavaria, Germany, which is located at the foothills of the Alps. The pilot actions took place mainly in the municipalities 'Burgberg' and 'Sonthofen'. Both settlements have faced hazardous events like floods and landslides in the past and must adapt their disaster management to the challenges of a changing climate. The high exposure of the alpine area to natural hazards, the high density of different types of land-use with specific requirements and demands, and finally, the high vulnerability and damage potential of industrial zones and settlement areas make the Oberallgäu an interesting pilot region in the Alpine Space.

### | BURGBERG:

The municipality of Burgberg is situated at the foot of the Grünten, geologically at the interface of tertiary molasse sediments and Alpine structures. The municipal territory stretches from 722 m a.s.l. in the Iller valley bottom to 1.783 m a.s.l. The main village of Burgberg is located on an alluvial fan of the torrent Wustbach and its tributaries, in the West bordering to the Iller valley bottom. The eastern part of the municipality is predominantly located in Alpine territory, whereas the western part in the Iller valley is mostly flat. Burgberg features a population of 3.108, the municipal territory of 1.598 ha is categorised in 51% agricultural area, 34% forest and 8.3% settlement and transport infrastructure. On average, every resident inhabits 50.2 sqm housing area. In the past, the torrents have caused considerable damage within the village area (1963, 1970, 2000). In light of the torrential event of 1970, the municipality has taken control measures at the creek's bed. As early as in the beginning of the last century, upstream control measures were taken at the Wustbach.

### | SONTHOFEN:

Sonthofen, the southernmost German city, is located at 743 m a.s.l. on a stretch between the Iller river and the Ostrach torrent. The southern part of the municipality ascends towards the Imberger Horn to an altitude of 1654 m a.s.l. Sonthofen is home to 20.990 residents, with the village of Altstädten being its secondary settlement center. With more than 61.000 tourist arrivals, making it the fourth largest tourist destination in the county of Oberallgäu, tourism is also a relevant economic sector. The municipal territory of 4.660 ha is made up of 40% agricultural area, 42% forest and 14.5% for settlement and transport infrastructure. On average, every resident occupies 45.6 sqm residential area.

The city has recently been affected by two flood events in 1999 and 2005. In the meantime, flood control measures (retention, dam improvements, bridge retrofitting) have been taken, minimising the hazard potential particularly of the Iller river. The torrent Starzlach runs through the eastern part of the municipality and has repeatedly caused considerable damage in the village Winkel.

### *Description of activities*

The activities in the Oberallgäu with focus on Burgberg and Sonthofen implied the identification of different methods of danger zone planning on local level and the development of recommendations for risk management in particular with respect to land use management and planning. For the project's pilot municipalities of Burgberg and Sonthofen, settlement development scenarios for the year 2028 have been elaborated, combining demographic trends, trends in residential area per person, growth and decline conditions with strong or weak regulatory approaches in municipal land policy. Hazard maps developed at the Bavarian Environment Agency combined with land use data were used as basis for the derivation of future land use scenarios. An integrative GIS-based analysis identified potential conflicts for the pilot municipalities. The gained information was presented to municipal representatives as a basis for a local risk dialogue.

Moreover, existing knowledge about natural hazards, available data sources and first recommendations are summarized in a booklet, which will be disseminated among all Bavarian municipalities in the Alpine area. A conference was organised for local stakeholders and mayors to provide a platform for information exchange among the Alpine municipalities.

### *Objectives*

It was the major aim of the pilot action to identify and address deficiencies of risk awareness to the field of natural hazard management and climate change. A risk dialogue needed to be initialized and an expert network established to provide municipalities with all necessary means to inform about risks and coping/adaptation strategies. Furthermore, the activities aimed at supporting the implementation of hazard information into local and regional planning processes and political planning decisions while considering local demographic and economic future development.

### *Major findings and recommendations*

- Risk awareness of communities depends on the actuality of damaging events and should be improved and maintained with publicity and awareness training
- Risk awareness of the responsible persons in communities of climate-related dangers is very differently developed. The willingness to analyze the risks estimated through climate change to work on them and search for answers is not yet present in Bavarian cities and communities as it is in other alpine countries (e.g. Switzerland, Austria)
- Municipalities still lack a climate adapted land use management. Long term strategies and measures are often superimposed by day-to-day business of the municipal administration. Synergies exist between adapting land use for settlement and infrastructure to spatial effects of climate change and efforts to contain urban sprawl in Alpine valleys.
- For the time being, a risk dialogue is an appropriate measure for awareness raising.
- Research has shown that unlike other alpine countries (e.g. Switzerland) Bavaria still lacks an integral risk management.

It is recommended to produce risk maps which covers all different risks such as landslides, mudflows and rockfalls, avalanches, and flooding for a thorough risk evaluation. Risk maps have to be exactly by plot to find their way into a strategy of land resource management on local level. Moreover, it is crucial to establish a continuous risk dialogue with communities and citizens at regional and local level, raise awareness and trigger the implementation of adaptation measures and to minimize risks. This should be part of an integral risk management that should be installed state wide.

### *Conclusion*

The pilot activity in the Oberallgäu showed that risk awareness and the adaption of land use planning to climate change is negligible in the municipalities. Although hazard maps are available, they are hardly used for local and regional planning processes. Thus, there is definitely a need to establish a continuous risk dialogue with the local decision-makers and with the citizens. A conference was hold and a booklet disseminated to initialize risk communication among Bavarian alpine municipalities.

Please find more information on [www.adaptalp.org](http://www.adaptalp.org) → Technical Report → WP 7 → Action 7.3

- Final Report of Workshop
- Booklet “Living with Alpine Natural Hazards” (German)
- Abstract of Booklet (English)
- Final Report of activities in Burgberg and Sonthofen

## **5.3 | SUMMARY AND OVERALL RECOMMENDATIONS FOR THE ALPINE SPACE**

In the three aforementioned pilot areas a broad variety of activities and actions have been conducted throughout the project runtime ranging from background research and education measures to an intensive communication with municipalities and local stakeholders.

Taking into account that risk communication and hazard management requires precise and high resolution data and maps new analyses were elaborated to facilitate discussions and highlight conflict areas in the municipalities. To guarantee a long-term impact a book was published informing about extreme hazardous events in the last centuries in Austria. Thus, an important step was made to enhance the data base of historical events and to improve information material that is urgently needed to enter in a risk dialogue with alpine municipalities.

A risk dialogue was initialized within all pilot areas with mayors, local administration and stakeholders by means of face-to-face communication or public events. Risk awareness differs extremely between the single municipalities in the Alpine Space. Often the degree to which a municipal disaster management is established depends on single persons in a municipality and financial support provided after an extreme event in the past. However, it is inevitable to find ways to disseminate information on natural hazard and risk continuously, especially in times of climate change.

Education is another important aspect for risk communication and awareness raising. The Biber Berti website is a crucial component of risk education in the Alpine Space. The teaching material is adapted to the needs of children and can be used at schools throughout the Alps. By reaching the young people an important step towards sustainable risk communication can be done.



From the experiences made during the work in the pilot areas the following recommendations for a climate change adapted and sustainable municipal development can be derived:

- It is crucial to pass on the experiences made with natural hazards in a municipality to the next generations to maintain a certain degree of consciousness within the community.
- By combining technical protection measures with land use restrictions or the set up of retention areas a high level of security can be created.
- Spatial planning and decisions with regard to municipal development should always have a look in the future and not only consider changing environmental conditions but also taking socio-economic and settlement development trend analyses into account.
- More compact settlement structures and less scattered settlements reduce the costs for protection measures. This should be considered in future spatial planning.
- Risk communication must start with our children (risk education) and needs to be an essential component of disaster risk management in the municipalities. Regular events need to be organized that guarantee the involvement of authorities, experts, stakeholders and also affected citizens.

Altogether it can be stated, that implementation of adaptation measures and the awareness of risks of a changing climate is still largely missing. First steps have been made, however, for the future it is important to find a way to reach not only single municipalities or regions but to raise awareness of all municipalities in the Alpine Space prone to natural risks. The municipalities need a complete compilation of data and information about the risks they are facing at the moment or in the upcoming decades. Furthermore, some efforts are still required to identify the right pathways of communication between administrations, stakeholders and the public. Additionally, the most appropriate incentives, including not only financial support, have to be identified.

## 5.4 | WP7 PARTNERS

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## 5.5 | REFERENCES

Hagen, Karl; Andrecs, Peter, 2009: Mass movement processes under changing climatic and socio-economic-conditions. IN: Zhelezov, G., Sustainable Development of Mountainous Regions, Sofia, Bulgaria, p. 19-32



## ANNEX 1: GLOSSARY

TERM	DEFINITION
acceptable risk	This corresponds to the level of loss that a community considers acceptable in relation to pre-existing social, economic, political, cultural, and technical conditions. In other words, it is the level of risk beyond /or below which a society does not intend to invest resources for its reduction (for example, because the investments surpass the benefits).
danger	A potential or evolving natural process that can produce negative effects for man or for the environment. Danger is represented by the intensity of the process and by the area involved.
cost-effectiveness	The relationships between (annualised) costs of a risk reduction measure and the effectiveness (in terms of annualised monetary values of reduced damages) is a key factor in decision-making and helps to select the most sustainable and appropriate measure (or a combination of measures) from all possible solutions.
element at risk	The entity (for example, people, property, economic activities, services and infrastructures, etc.) exposed to a hazard.
hazard	The temporal probability that an event of a given intensity involves a certain area during a specific time interval. Hazard includes latent conditions representing a future threat for man and the environment and is generally expressed in terms of annual probability.
integrated risk management	Integrated risk management in dealing with natural hazards in a wider sense is part of the holistic understanding and consideration of natural risks, composed by risk analysis, risk evaluation and risk reduction and risk management in a narrower sense. Integrated risk management incorporates all measures that contribute to the reduction of damage caused by natural hazards. These include, for example, emergency management during disasters, the maintenance of protective structures, repair work, the maintenance of protective forests and structural measures.
intensity	The geometric and mechanical severity of a phenomenon. Intensity can be expressed on a relative scale or in terms of one or more characteristic dimensions of the phenomenon (volume, velocity, energy, etc).
magnitude	A measure of the intensity of some natural phenomena. In particular, in the field of natural risks, the term magnitude is used to express the energy of an earthquake and the volume of the debris flows.
potential damage	The amount of potential losses in case of an event of certain intensity. Conventionally, the expected damage (D) is expressed as the product of the value of the element at risk (E) and its vulnerability (V).
reconstruction, restoration	Actions carried out following an event in order to restore the areas involved to the pre-event living conditions, with particular regard to risk reduction. This generally consists of two main phases: an initial phase consists of the restoration, even if only temporary, of the most important infrastructures (telecommunications, energy, strategic roadways, etc.) during the event and immediately following; a second phase consists of reconstruction of an undetermined duration that must be planned and regards all the structures and infrastructures.

TERM	DEFINITION
residual risk	Residual risk is the risk that remains when all protective measures have been implemented and is closely related to the question as to which risks are acceptable to individuals and society.
risk assessment	Process of analyzing and evaluating the probability of adverse effects caused by natural hazards
risk dialogue	Risk dialogue should help to inform the authorities, politicians and society about the need for a concerted preventive effort. It is fundamental to risk-appropriate decision-making when planning safety measures and when prioritising the corresponding investments. A sound risk dialogue also enables participative decision-making processes. In addition, it is an opportunity for the proper consideration of climate scenarios and their potential consequences.
risk management	Risk management is the process of analysing and evaluating risks and finding solutions for the reduction of unaccepted risks.
safety	Status for which the remaining risk (residual risk) is rated as being acceptable.
vulnerability	The degree of loss of a certain element of risk, or groups of elements, due to the impact of a natural phenomenon of a given intensity. It is expressed in qualitative and quantitative terms on a scale from 0 (no loss) to 1 (total loss) and is a function of the intensity of the acting process and the typology of the element at risk.

## ANNEX 2: PROJECT PARTNERS



Bayerisches Staatsministerium für  
Umwelt und Gesundheit



Bavarian State Ministry of the Environment  
and Public Health (StMUG)



Bayerisches Landesamt für  
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lebensministerium.at

Federal Ministry of Agriculture, Forestry, Environment  
and Water Management (BMLFUW)



Autonomous Province of Bolzano (WBV)



Ministry for the Environment, Land and Sea (MATTM)



Geological Survey of Slovenia (GeoSZ)



CIPRA Deutschland (CIPRA)





Regional Government of Carinthia (BWV)



Regional Government of Tyrol (WWT)



Piemonte Regional Agency for Environmental Protection (ARPA)



Aosta Valley Autonomous Region (RAVA)



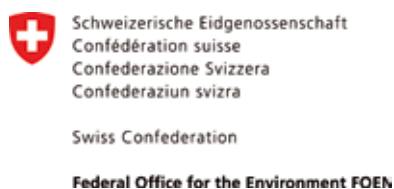
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CEMAGREF



EURAC Research



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