StartClim2013

Adaptation to climate change in Austria: "Water"

Final Report

July 2014

MINISTERIUM FÜR EIN LEBENSWERTES ÖSTERREICH

bmwfw Bundesministerium für Wissenschaft, Forschung und Wirtschaft

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Project Leader

Institute of Meteorology
Department of Water, Atmosphere and Environment
BOKU - University of Natural Resources and Life Sciences Vienna
Univ.-Prof. Dr. Helga Kromp-Kolb

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Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management
Austrian Federal Ministry of Science, Research and Economy
Federal State of Upper Austria
Austrian Federal Forests
Federal Environment Agency

Administrative Coordination

Federal Environment Agency

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Abstract

StartClim has been studying the topic of adaptation to climate change since 2008. StartClim2013 focuses on the subject of “water”. Three projects addressed issues related to floods and runoff, two studied climate-induced changes to aquatic habitats and the effects on domestic fish species and one project examined whether climate change causes an increased occurrence of agricultural pests. Lastly, one work investigated how natural disaster management could take issues of gender and social diversity into account.

The seasonal distribution of runoff in Alpine catchments is markedly influenced by the cryospheric contribution (snow and ice). Long-term climate change will alter these reservoirs and consequently have a direct impact on the water balance caused by changes in temperature and precipitation and an indirect impact linked to glacier retreat.

Mean runoff and annual runoff maxima were analysed in the catchment of the river Ötztaler Ache at the runoff gauges Brunau (890km², 11% glaciated), Obergurgl (72.5km², 28% glaciated) and Vent (165.4km², 31% glaciated; glaciation percentages from 2006).

Under consideration of the climate scenarios used, model results show a reduction in glacier volume and area to less than 20% of the current ice cover by the end of the 21st century. Thus, runoff from ice melt will decrease in the summer months while an increase in runoff can be expected in spring and autumn, due to a rise in snowline altitude. Overall, an increase in mean runoff in spring and a decrease in average runoff in summer are likely. This will cause a shift in the seasonal distribution of annual runoff maxima from July and August to May and June. These changes will have an impact on flooding scenarios and should be taken into account in flood risk predictions.

Even before the implementation of the EU Floods Directive, member states were urged to pay greater attention to the issue of flood risk management. Development pressure, especially in Alpine regions, and the associated increase in impermeable surfaces, combined with the siting of new developments in areas of high flood risk, represent an ever-increasing challenge for flood risk management.

Based on several good-practice examples, options for interdisciplinary, transsectoral and sustainable development of areas with high flood risk were examined. The key issue is to increase cooperation between communities. Clearly targeted information about flood risks and development implications will help raise awareness and create a better understanding of the need for an integrated approach to the development of river catchment areas. Interdisciplinary and participative visioning processes for river areas, designed to formulate regional objectives across communities, may be able to halt or even reverse the trend towards ever-increasing flood damage potential in high-risk areas.

Strategic funding on a regional and national level, developed on the basis of the aforementioned visioning processes and regional objectives, can help compensate for imbalances between upstream communities and those further downstream, thereby supporting a proactive and preventative approach to flood risk management. The real question to ask in all this is: “How can we best develop our living environment with – not against – the river?” and this will also have to incorporate possible climate change scenarios.

Damage caused by floods has increased drastically in Austria and all across Europe over the last decades. This is caused on the one hand by land use changes in the catchments and valleys, which increased flood risk downstream (e.g. the loss of floodplains) and on the other hand by an increase of high-value land uses on flood-prone areas. Therefore, the Austrian Strategy for Adaptation to Climate Change, as well as the EU Floods Directive, demand the preservation of existing and the restoration of lost floodplains in the context of an integrated flood risk management.

The objective of one of the StartClim2013 projects was to examine the connection between loss of floodplains and flood risk. Analysis of recent and historic aerial photos of the last 60 years at the Tyrolean Inn showed a strong shift from flood-adapted land uses (fields and grassland) to more flood-sensitive uses (settlements, industry & commerce, special areas and transportation areas), which now cover one third of the valley. In order to protect these higher value land uses, flood defence works have been constructed, separating the river from the adjacent land. Overall, this has led to increased flood risk, not just locally for nearby residents, but also on a larger scale for settlements further downstream. Flood-adapted uses on floodplain land, on the other hand, do not increase flood risk. Considering the anticipated increase in flood events as a result of climate change, it is recommended to preserve or even reconnect floodplains as part of an integrated flood risk management.

Headwaters of Alpine rivers in Austria are characterized by a predominance of brown trout, which is optimally adapted to cold water temperatures, high oxygen concentrations and high water flow. Climate change is likely to reduce trout habitats or shift brown trout habitats to higher altitudes. However, the effects of high temperatures on the behaviour of brown trout in the summer are not well understood and insight is missing on whether or how adaptive strategies can be developed to mitigate the impacts of climate change on brown trout populations.

Observation of brown trout combined with water temperature measurement in the headwaters of the river Traun during summer 2013 provided new insights into trout behaviour in relation to high water temperatures. Watercourses in the study area already showed significantly higher water temperatures in summer, due to the warming effect of connected lakes. Temperatures measured in the study area in summer 2013 showed clearly that these habitats were too warm for brown trout and negative effects on fish growth and mortality are likely. Observation of trout behaviour indicates that the fish prefer deeper and cooler areas during warm periods.

Such habitats are, however, not accessible in all areas, due to artificial barriers (e.g., dams and weirs) and low water levels in summer. Instead, brown trout compensate higher temperatures with reduced activity during the daytime. Competition for space and food potentially aggravates the negative effects of high temperatures. Adaptive strategies for areas where brown trout are affected by thermal stress during summer should therefore focus on conserving and maximizing groundwater inflow, minimizing barriers in creeks and rivers, optimizing fisheries management and enhancing habitat diversity for brown trout.

Climate change affects fish not just through increasing water temperature. In addition, decreasing flow rates in summer reduce the volume of habitat available, while nutrient concentrations increase. Here, land use has a more pronounced effect on flow rates in summer than air temperature.

These interrelations were quantified for a representative set of Austrian rivers and streams. Based on these relationships, scenarios were developed for 2050, predicting nitrite concentrations, flow rates and key fish species occurrence in summer. Summer values were used, as for cold-water species the effects of climate change are likely to be more critical during the summer months.

Temperature does not only affect fish populations, but also nitrite concentrations. Nitrite concentrations increase with reduced flow rates and increasing temperatures. The substance is toxic to fish and, in combination with rising temperatures, is expected to limit the occurrence of cold-water fish species. The effect is most pronounced for the grayling, a cold-water fish, but, interestingly, barbel and nase carp – two species typical for larger rivers – are also affected. Large areas of arable farming in the catchment area leads to lower flow rates and higher nitrite concentrations in summer. Wetlands are able to mitigate these negative effects to some extent.

According to the IPCC emissions scenario A1B, by 2050 the mean air temperature in summer will be 3 to 4°C (maximum 5°C) higher compared to 2000. Considerable loss of habitat for cold-water fish species can be expected as a result, whereas the distribution of species that are less sensitive to temperature is likely to expand. In the case of potentially invasive species, such as top-mouth gudgeon, this is expected to have negative effects on other fish species.

The impacts of climate change on habitats also facilitate the survival of other invasive species in Austria. Particularly problematic are agricultural pests, like wireworms, which were studied in StartClim2013. The larvae of click beetle species (*Coleoptera*, Fam. *Elateridae*) can cause substantial damage to agriculture by feeding on crops. As climate change is expected to raise mean temperatures, indigenous thermophile wireworm species will be able to increase their pressure on crops, while new species from the Mediterranean may migrate further north. Dealing with increasing wireworm pressure will require a practical tool for wireworm damage risk analysis.

Both soil temperature and soil moisture decisively influence larval movement within the soil column. If conditions are favourable, wireworms will be located near the surface, where they can feed on the plants' subterranean parts. If the topsoil is too hot and dry or too cold and moist, they migrate into deeper soil regions, where conditions are more favourable. Based on this relationship, the wireworm prognosis model SIMAGRIO-W, developed in Germany, calculates the percentage of a given wireworm population that is located in the upper 15cm of the soil column (= damaging zone), and thereby the damage risk. If high wireworm activity is expected in the damaging zone, it may be advisable, for example, to delay the cultivation of maize or to bring the potato harvest forward. Furthermore, the model can assist with density measurements or control measures, e.g. intensive soil cultivation, which needs to be conducted when the larvae are near the surface.

In western Germany, initial validations of the model showed more than 80% correct predictions. In our study, SIMAGRIO-W was tested for its applicability to Eastern Austrian agriculture, by comparing the model's predictions for wireworm population percentages in the topsoil layer at four study sites in Eastern Austria to larvae counts at the same sites. This validation showed a much lower hit rate of 54% and only two veritable predictions regarding peaks of wireworm activity. The weak hit rate was primarily due to the fact that SIMAGRIO-W assumes an activity maximum at 11°C, while, at the experimental sites, high wireworm activity was measured at temperatures of up to 26°C. This discrepancy may be explained by differences in temperature optimum and tolerance between the *Agriotes* species dominating in Eastern Austria (e.g. A. *ustulatus* and A. *brevis*) and in western Germany (e.g. A. *obscurus*), where the model was developed. If the thermal preferences of regionally dominant wireworm species are factored in, SIMAGRIO-W should also be able to make a valuable contribution to the prevention of wireworm damage in Eastern Austrian agriculture. Consequently, further studies aimed at adapting the model to regional conditions are strongly recommended.

Climate change is not gender-neutral. Women and men are affected in different ways by natural disasters – which are likely to increase due to climate change. Furthermore, policies and climate change mitigation strategies, as well as adaptation instruments and measures, have different impacts on women and men.

Using the debris flow in 2012 in St. Lorenzen, a village in the municipality of Trieben in the Palten Valley in Styria as a case study, the research team tested methods, instruments and approaches for a Gender Impact Assessment in the context of climate change and natural hazards. Within this project, the term "gender" is defined in a wider sense as "gender+" and includes differences between individuals and groups in terms of their life stage and situation, social and cultural background.

The results show that as of yet there is little awareness among the population as well as within emergency response teams of group- and gender-specific aspects, but that raising awareness of different gender- and group-specific needs and requirements may not only improve emergency responses, but also support people's ability to help themselves and strengthen community resilience.

The analysis also revealed that people without strong local, social networks tend to be worse affected by the impacts of a natural disaster. The results of this research back the theory that the integration of gender-specific aspects in the management and prevention of natural disasters forms part of a comprehensive and effective approach. The objective is not to help everybody in the same way, but to help everyone equally *well*. This requires a differentiated approach that respects different needs and allows all groups to participate equally in decision-making processes.

The project furthermore makes suggestions for gender-sensitive analysis tools for natural disasters in an Austrian context as well as practical tools for regional and local governments and practitioners in disaster management.

1 The StartClim research programme

The StartClim climate research programme is a flexible instrument. Because of the short project duration and annual allocation of project topics, it can react quickly to topical aspects of climate and climate change. It is financed by a donor consortium currently consisting of nine institutions:

- Federal Ministry of Agriculture, Forestry, Environment and Water Management
  (2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013)
- Federal Ministry of Health
  (2005, 2006, 2007)
- Federal Ministry of Science and Research and Federal Ministry of Economy, Family and Youth (since 2014: Federal Ministry of Science, Research and Economy)
  (2003, 2004, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013)
- Federal State of Upper Austria
  (2012, 2013)
- Austrian Federal Forests
  (2008, 2009, 2010, 2011, 2012, 2013)
- Oesterreichische Nationalbank
  (2003, 2004)
- Austrian Hail Insurance
  (2003, 2004, 2006, 2007, 2008)
- Federal Environment Agency
  (2003)
- Verbund AG
  (2004, 2007)

StartClim has been studying adaptation to climate change since 2008. In StartClim2012 and 2013, the programme objective was to deliver valuable contributions to the implementation of the Austrian National Adaptation Strategy.

The seven StartCim2013 projects focused on the subject area “water”. Different aspects relevant to adaptation to climate change were explored. The projects investigated thermal stress for brown trout in the headwaters of the river Traun during summer, loss of floodplains and flood risk in the context of climate change, runoff scenarios in the Ötztal valley (Tyrol, Austria) considering changes of the cryosphere as a result of climate change, recommendations for changes to regional development and spatial planning in areas of high flood risk, an interdisciplinary analysis of the response of Austrian river systems to climate change in terms of fish fauna and nutrients, development of a Gender Impact Assessment in the context of climate change adaptation and natural hazards, and an assessment of the suitability of the wireworm prognosis model SIMAGRIO-W, developed in Germany, for Eastern Austrian agriculture.

The StartClim2013 report consists of an overview of the results in German and English along with a separate documentation that contains detailed descriptions of the individual projects by the respective project teams. All StartClim2013 reports and documents will be available for download on the StartClim website (www.startclim.at). Furthermore, a limited number of CDs containing all StartClim reports and a folder with a short summary will also be made available.

2 StartClim2013.A: Thermal stress for brown trout in the headwaters of the river Traun during summer

Headwaters of Alpine rivers are characterised by a predominance of brown trout, which is well adapted to cold water temperatures, high oxygen concentrations and fast water flow. This fish species thrives in low water temperatures between 3°C and 19°C and shows reduced mobility in the summer months, which makes it susceptible to the effects of climate change. Rising temperatures are likely to reduce trout habitats, i.e. shift them towards higher altitudes. However, exactly how periods of high temperatures in summer affect the behaviour of brown trout is not well understood, although this could help in developing adaptive strategies to mitigate the effects of climate change on the brown trout population.

For this purpose, this StartClim-project used temperature measurements in the headwaters of the river Traun in combination with observation of brown trout behaviour to evaluate possible adaptive strategies. A characteristic feature of the study area is the warming effect of several lakes, which feed into the tributaries of the river Traun. Consequently, even today, river temperatures are already showing a notable increase during the summer months.

Temperatures measured at 12 sampling sites in the Upper Traun river during summer 2013 showed clearly that conditions were too warm for brown trout. Reduced growth and higher mortality rates are likely at temperatures of more than 26°C (Fig. 1). The summer months are the key growth period for brown trout and the time when energy reserves for reproduction in the autumn are accumulated. Excessively high water temperatures in summer are therefore likely to affect reproduction and limit population growth of the species.

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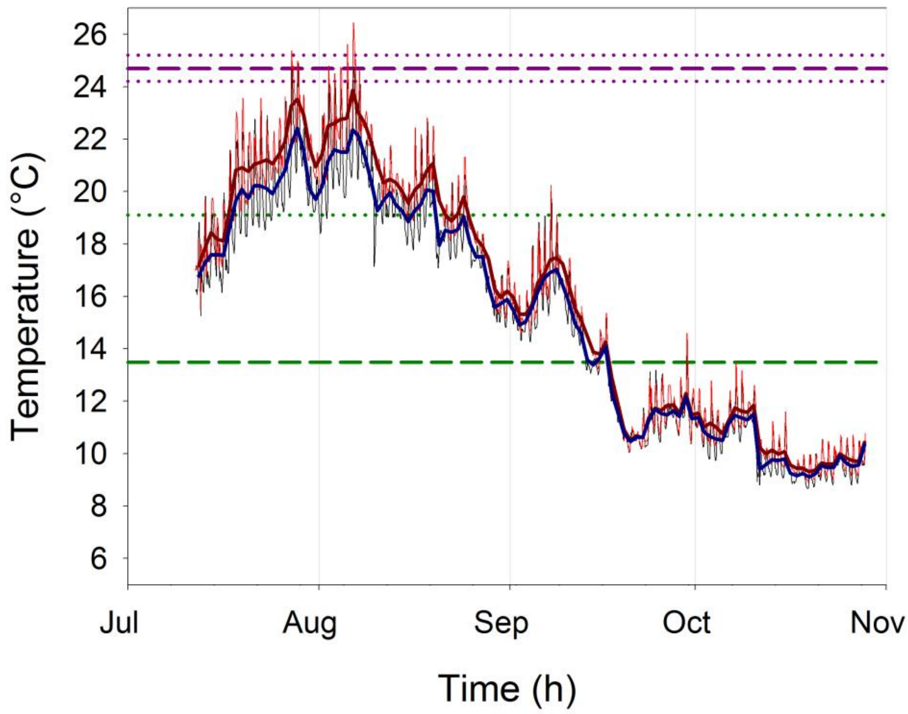

Fig. 1: High water temperatures during summer 2013, based on the example of Toplitzbach creek in the headwaters of the river Traun. Hourly measurements (thin lines) and daily averages (thick lines) of water temperatures measured at an elevation of 719m amsl (red lines) and 709m amsl (blue lines). Reference lines indicate optimum temperatures for brown trout (dashed green line), the threshold where negative effects on growth are expected (dotted green line) and the range of the upper lethal temperature (purple line), which was exceeded for a short time during the hot period at the end of July and beginning of August 2013.

Water temperatures decreased with increasing distance to the lake outflow in all creeks in the headwaters of the river Traun (see Toplitzbach example in Fig. 1). Results of temperature measurements also indicated that groundwater inflow has a greater cooling effect on Alpine creeks than the extent of shaded areas. The cooling effect was most notable at deeper parts of the creeks and rivers.

Observations of the behaviour patterns of over 8,000 brown trout at 16 different locations revealed that brown trout prefers deeper and cooler habitats during the summer months. Such habitats are, however, not accessible in all areas due to artificial barriers and low water levels. Instead, brown trout compensate the greater energy demand at higher temperatures with reduced activity during daytime, shifting their main activity to the cooler night hours.

An increase in the overall number of fish species due to migration of lake species into creeks and rivers during the summer seemed to have no noticeable effect on the number of brown trout in their habitat. Immigration of predatory species, such as perch, could, however, have a considerable effect on the number of younger and smaller brown trouts. Additionally, the presence of rainbow trout was documented at all sampled locations in the headwaters of the river Traun, with the exception of the Toplitzbach and Stimitzbach creeks. Rainbow trout is a non-indigenous species originating from North America. Rainbow trout and brown trout share the same food sources and are consequently direct competitors. Such competition for space and food has the potential to aggravate the negative impacts of increasing temperatures.

To mitigate the effects of rising water temperatures on brown trout populations, the study recommends optimizing habitats and making adjustments to fisheries management as suitable adaptation strategies. Enabling sufficient influx of cooler groundwater is of particular importance and any construction measures on riverbeds that seal off or limit groundwater inflows should be avoided. Rather, creating a wider range of microhabitats, e.g. through dead wood, stones and rocks, could support brown trout populations. Riverbed enhancement measures need to offer more opportunities for brown trout to retreat and seek shelter during periods of high temperatures and low water levels. Furthermore, preserving, or even creating, deeper – and therefore cooler – areas within the river will also help reconnect with groundwater inflows and thus enhance the cooling effect further.

Barriers, such as dams, should be removed as far as possible, enabling fish to migrate towards cooler areas in the summer, bearing in mind lower water flows as well as the trout's reduced activity levels during hot periods. However, any habitat creation or river re-naturalisation measures need to be carefully timed, as construction works in the summer months will cause additional stress for the trout, while sediment transfer could potentially damage adjacent habitats. Fisheries management, meanwhile, needs to focus efforts on reducing non-native competitors of brown trout, such as the rainbow trout. For this purpose, incentives could be created for anglers to catch higher numbers of this species, thereby helping to reduce the rainbow trout population.

Another issue within fisheries management is the restocking of Alpine creeks and rivers with high numbers of young brown trout. This substantially increases population density, thereby also increasing competition for food and space, which in turn can impede growth and lead to higher mortality rates within the brown trout population. This compounds the effects of higher temperatures and low water flows in summer, which already increases population density. Restocking is therefore likely to aggravate the negative impacts of climate change and adapting the practice or abandoning it altogether should be considered.

3 StartClim2013.B: Loss of floodplains and flood risk in the context of climate change

Damage caused by floods has increased drastically in Austria and all across Europe over the last decades. This is caused partly by land use changes in catchments and valleys, which has led to increased flood risk further downstream through the loss of floodplains, but also by the accumulation of higher-value land uses in flood-prone areas. Superimposed on these developments is climate change, which is expected to further increase rainfall in the future. It is therefore important to understand the extent to which floodplains are able to mitigate floods. In this project, the research team looked at a number of historic and predicted scenarios to establish the importance of floodplains for flood risk mitigation. The results offer important data to inform and validate decisions in the context of integrated flood risk management.

For selected Austrian rivers, historic analyses combined with modelling of potential future scenarios were carried out to determine how flood risk and damage potential would change if rivers were given more space. Recent and historic aerial photographs were used to evaluate land use changes on floodplains within the last 60 years: a strong shift from flood-adapted uses (fields and grassland) to flood-sensitive uses (settlements, industry & commerce, special areas and transportation areas) was clearly notable. Fig. 2 shows this for the Tyrolean Inn. Between 1950 and 2010, the proportion of grassland here was reduced from 72% to 51%. At the same time, flood-sensitive land uses increased similarly, by 21%, and now cover one third of the valley.

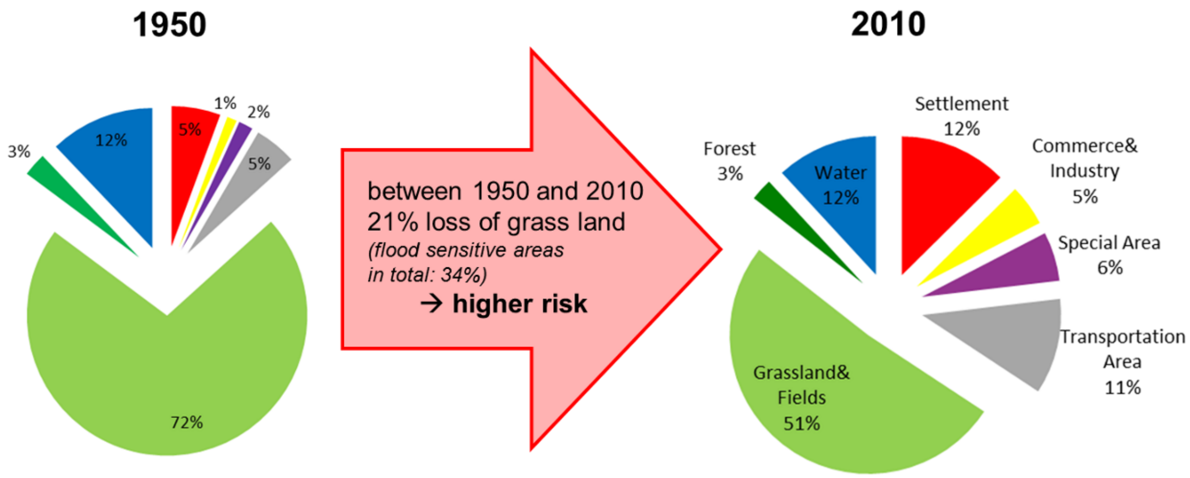

Fig. 2: Changes in land use along the Tyrolean Inn between 1950 and 2010

These developments have not only increased damage potential in flood-prone areas, but have also led to the loss of retention space, since former floodplains are now subject to higher-value uses, and therefore often separated from the river through flood defence works. Taken together, this has increased flood risk not only in the immediate vicinity, but also on a larger scale for settlements further downstream. Fig. 3 shows how the higher flows of the flood wave of 2005 (inflow wave) would have been flattened and temporally delayed by the retention effects of still existing floodplains in 1950 (outflow wave 1950). Comparing this with the scenario of 2010 (outflow wave 2010), the reduction would have been only about half of this and the flood peak would have been delayed by only 30 minutes instead of one hour.

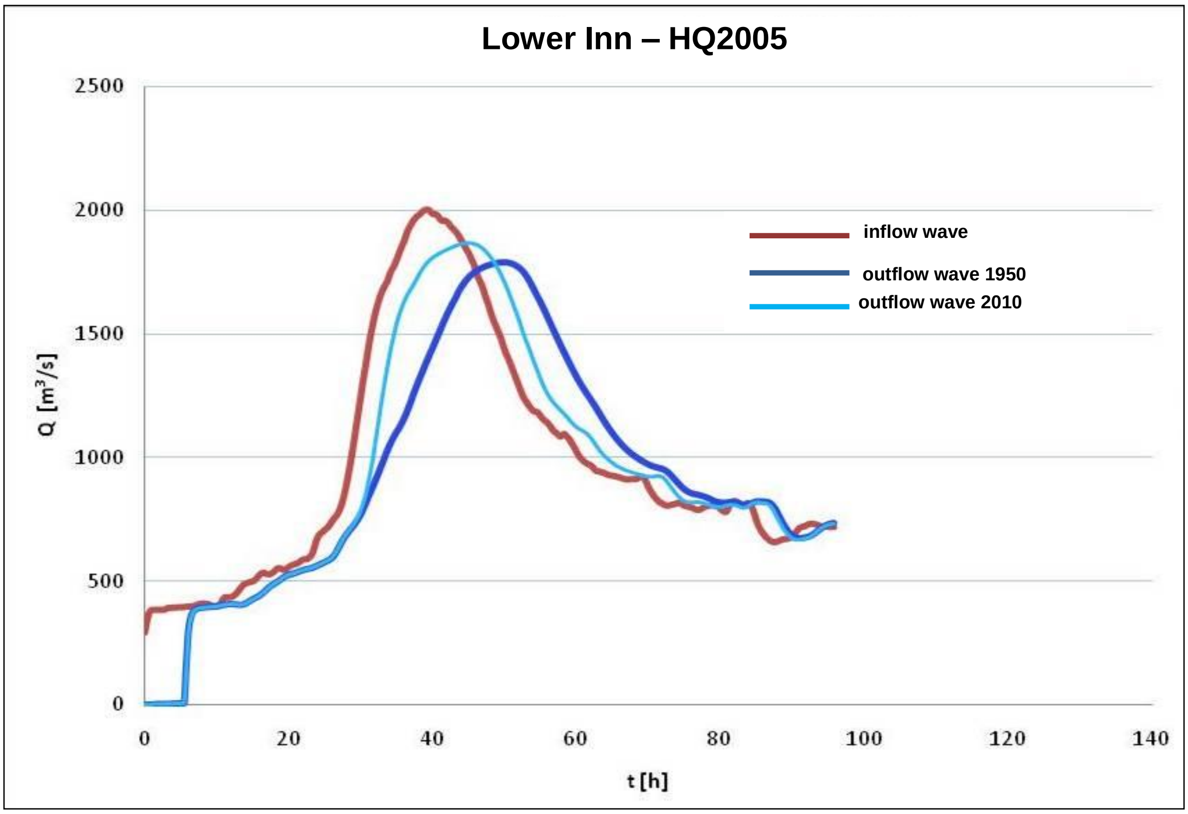

Fig. 3: Flood wave transformation of the 2005 flood as a result of floodplains along the Lower Inn (Jenbach to Kufstein) in comparison with 1950 and 2010

These findings are of importance for future flood risk management strategies and spatial planning, since floodplain losses continue apace, while climate change is predicted to lead to increased rainfall in the future. Especially for extreme rainfall events, the research project showed clearly that natural floodplains with flood-adapted uses represent a valuable buffer for mitigating such extreme events without increasing flood risk further downstream.

Both the Austrian Climate Change Adaptation Strategy and the EU Floods Directive call for the preservation of existing and the restoration of lost floodplains in the context of integrated flood risk management. The findings of this project serve to confirm and quantify the effectiveness of floodplains in flood risk mitigation und also demonstrate that natural floodplains are able to reduce flood intensity and minimize damage potential in flood-prone areas. Considering the potential effects of climate change, it is therefore highly recommended to preserve and restore floodplains and retention areas as part of an integrated flood risk management.

4 StartClim2013.C: Runoff scenarios in the Ötztal valley (Tyrol, Austria) considering changes to the cryosphere as a result of climate change

The seasonal distribution of runoff in Alpine catchments is markedly influenced by the cryospheric contribution (snow and ice). Long-term climate change will alter the glacial reservoirs and consequently have a direct impact on water balance, due to changes in temperature and precipitation, and an indirect impact linked to glacier retreat.

Glacierized catchments like the Ötztal valley in Tyrol are particularly sensitive to changes in the cryosphere and related hydrological changes. The Ötztal valley has a long history in Austrian and international cryospheric research and, as a result, comprehensive data on glacial development and changes over the past decades already exists. Furthermore, the economy of the Ötztal valley (tourism, hydropower etc.) is highly sensitive to changes in the natural environment.

In this study, future glacier scenarios for the runoff calculations in the Ötztal catchment were developed. In addition to climatological scenario data, glacier scenarios were calculated for the hydrological simulation. Direct effects of climate change (i.e. changes in temperature and precipitation) and indirect effects in terms of variations in the cryosphere were considered for the analysis of mean runoff and annual runoff maxima in the catchment of the river Ötztaler Ache at the gauging stations Brunau (890km², 11% glacierized (2006)), Obergurgl (72.5km², 28% glacierized (2006)) and Vent (165.4km², 31% glacierized (2006)).

Glacier outlines and glacier surface elevation changes of the Austrian Glacier Inventory were used to derive present ice thickness distribution in the Ötztal region. Scenarios of glacier area distribution were modelled using observed surface elevation changes and mass balance variations linked to climate change.

To balance the uncertainties of regional climate models, three different combinations of global and regional climate models (ARPEGEG-ALADIN, ECHAM5-REMO, ECHAM5-REGCM3) were used to derive changes in temperature and precipitation for the periods 2010–2039, 2040–2069 and 2070–2099 compared to the reference period 1985–2014. The low-pass-filtered daily change signal was added to the original meteorological measurements of 1986 to 2012 to analyse runoff changes over this 27-year period.

Runoff was simulated using the hydrological model HQsim, which was calibrated for the gauging stations at Brunau, Obergurgl and Vent. Runoff simulation was forced with glacier changes only, with changes in temperature and precipitation only, and with a combination of both: changes in climate and glacierization (Tab. 1). This was done to test the sensitivity of simulated runoff to different sources of forcing. Shifts in seasonal distribution of daily mean runoff and annual runoff maxima were analysed using the Pardè coefficient and directional statistics.

Glaciers first decrease in volume, before glacier area shrinks. The project's scenarios showed a reduction in glacier volume and area to less than 20% of the current ice cover by the end of the 21st century, with a glacier volume loss of 50% by 2050. The changes in glacier area have a significant impact on seasonal runoff levels. Especially in the summer months with high ice melt contribution, the loss of glacier area leads to a reduction of base runoff (glacial melt) (Fig. 4).

An increase in runoff caused by a higher snowline altitude can be expected in spring and autumn. The simulation that combined glacier change and climate change scenarios showed increased runoff in spring and reduced runoff in summer. Thus, annual runoff maxima will shift from July and August towards May and June (Fig. 5). The extent of this shift depends on the degree of glacierization. Within the Brunau catchment, with a relatively low percentage of glacierization, the annual runoff maxima will occur in spring, whereas in the Obergurgl and

Vent catchments, with a higher degree of glacierization, runoff maxima will occur most frequently in June.

In general, the study showed that runoff in the Ötztal catchment is not only sensitive to variations in climate, but also to changes in glacierization (Fig. 6). Thus, changes of the cryosphere have to be considered in scenario calculations for runoff and flood frequencies in glacierized catchments.

Tab. 1: Different combinations of climate signal and glacierized area used for the runoff simulations. The colours are equivalent in the following figures.

Glacier / climate	reference 2006	Glacier 2025	Glacier 2055	Glacier 2085
reference 1986-2012	REF	A1	A2	A3
period 2010-2039	B1	C1		
period 2040-2069	B2		C2	
period 2070-2099	B3			C3

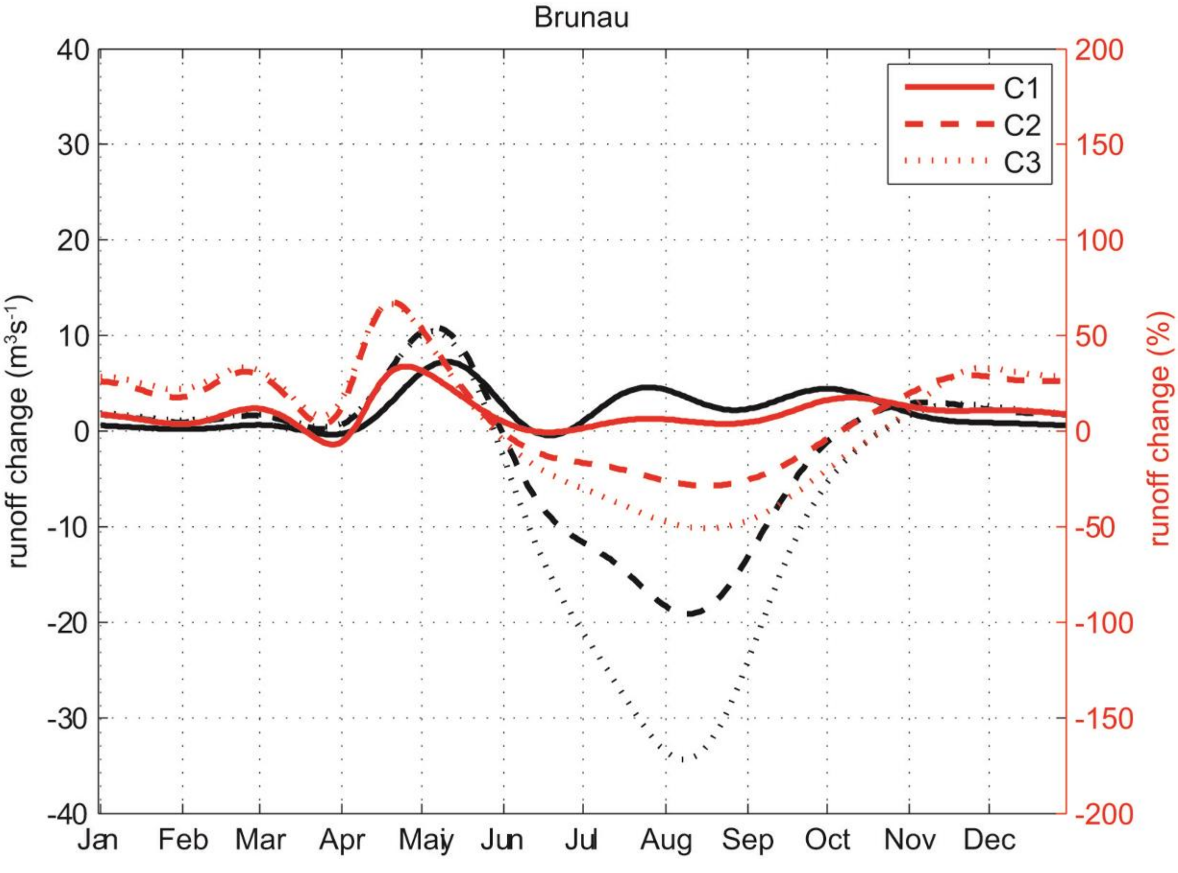

Fig. 4: Absolute (black) and relative (red) changes of runoff compared to runoff in the reference period 1986–2012 for the climate scenarios C1, C2 and C3 (Tab. 1) at the runoff gauge Brunau.

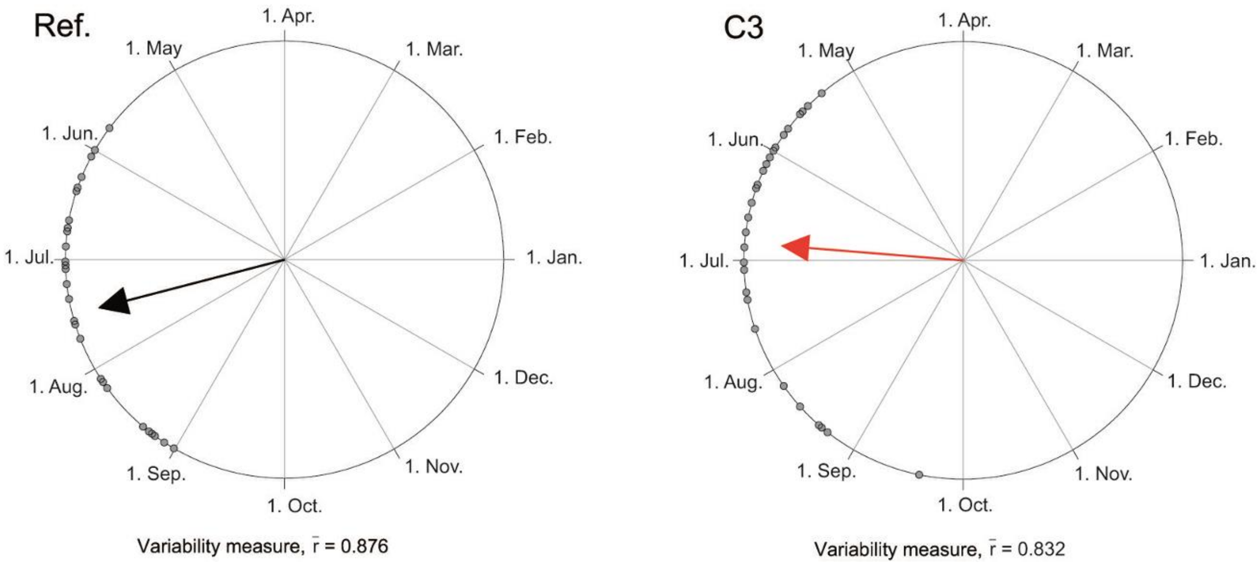

Fig. 5: Directional statistics of annual runoff maxima at the runoff gauge Brunau for the reference period (Ref.) 1986–2012 and for the simulation using scenario C3 (Tab. 1). The arrow shows the mean Julian day of the annual runoff maxima (points on circle). The length of the arrow is a measure of temporal variability r (given below the plot).

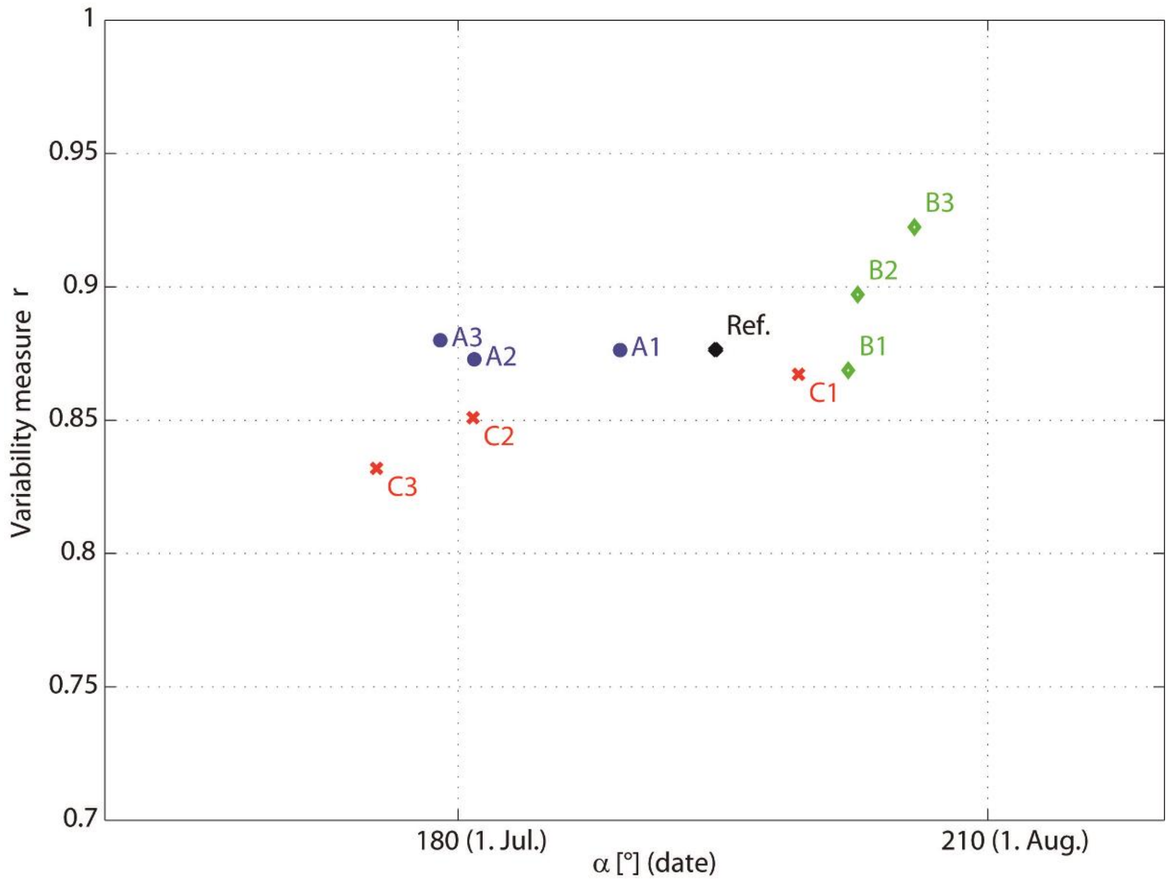

Fig. 6: Variability measure r plotted against the mean Julian day of annual runoff maxima simulated for different scenarios (Tab. 1) and the reference period at the runoff gauge Brunau.

5 StartClim2013.D: Recommendations for changes to regional development and spatial planning in areas of high flood risk

Even before the implementation of the EU Floods Directive, member states have been urged to pay greater attention to flood risk management.

Housing development to accommodate population growth and rising demands of space per family unit present an ever-increasing challenge for flood risk management in Alpine regions. Any kind of built development inevitably leads to an increase in sealed, impermeable surfaces, which, in turn, increases runoff speed and volume and aggravates flooding. At the same time, housing and infrastructure development is increasingly allowed to take place in areas of high flood risk, where in the past development was not permitted – and rightly so, as rivers need retention areas during times of high water levels. Land use and regional planning in Austria has not yet assumed the key role it ought to have in flood prevention and flood risk management. Strategic planning is an important instrument with the potential to reconcile the conflicting interests of facilitating built development and reducing flood risk. In this project, good-practice examples from Austria and abroad were used to explore tools that may enable strategic planning to take a more leading role in this.

To meet the above-mentioned demands within the existing legal planning frameworks, strategic planning instruments will need to be critically examined and adapted. Any development along rivers should be considered at all four levels of regional planning: i.e. formal protection of open spaces, economic aspects, such as compulsory insurance for certain high-risk areas, informal, e.g. through flood risk vulnerability assessments, and organisational, for example by strengthening local and regional networks.

One recent good-practice example is the *Blauzone* ("Blue Zone") in Vorarlberg in Austria, a formal-organisational as well as informative tool, which maps flood-risk areas to safeguard the "long-term protection of human spatial requirements, in particular space for housing and work" (FREI, KOPF 2011, page 6). In this, the regional planning authority works in consultation with the communities affected to decide which areas should be designated as "Blue Zones".

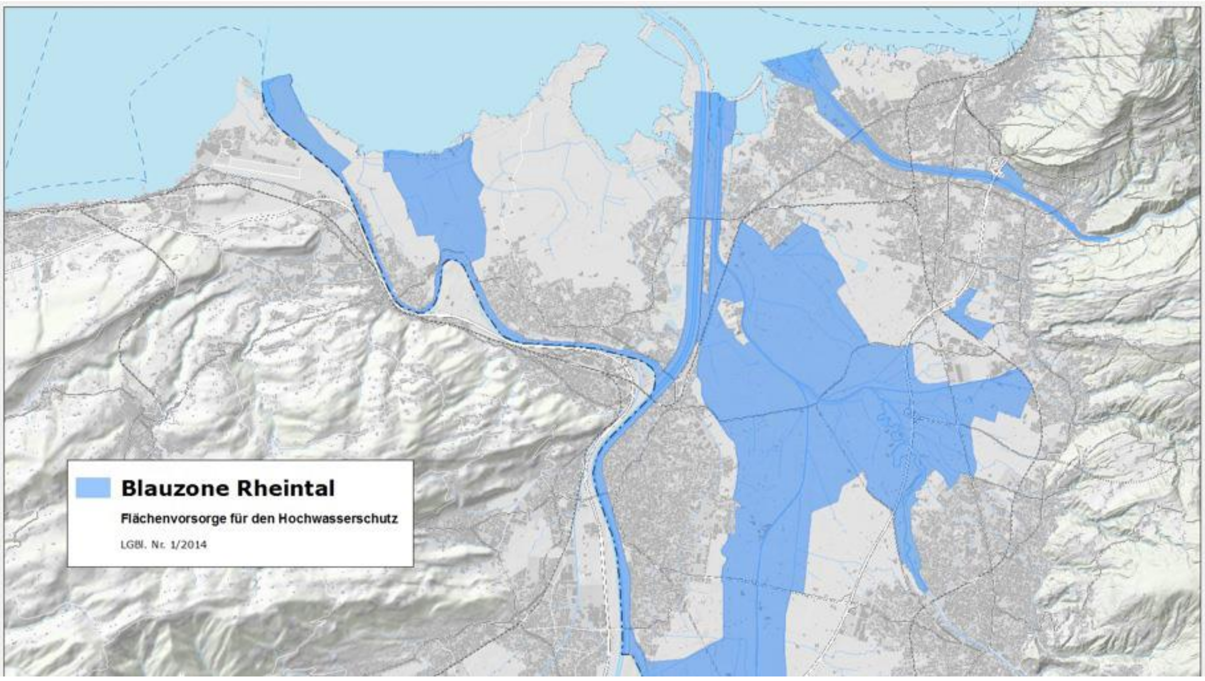

Fig. 7: Plan showing the *Blauzone* (source: Raumplanung/Land Vorarlberg)

An essential starting point in strategic and regional land use planning is to include a clear and legally binding designation of high-flood-risk areas in relevant plans, such as flood risk management plans or local zoning plans. Moreover, regional development plans and land use strategies need to consider the space rivers need for flooding. Local planning departments can then base development decisions on this guidance.

To implement these concepts in practice, all stakeholders need to have the opportunity to voice their concerns and interests and to develop mutually acceptable solutions together. Consultation processes (informative as well as informal) are a useful tool in negotiating development options and jointly developing visions and concepts. Clear information is an important prerequisite to decision-making and this can be provided through local or regional flood risk models (see project StartClim2013.B, GPB DANUBE FLOOD RISK – pilot community Krems).

Interdisciplinary and participative processes to develop visions for river areas and formulate regional objectives across communities may be able to halt or even reverse the current trend towards ever-increasing flood damage potential in high-risk areas. The key to sustainable regional development in high-flood-risk areas lies in promoting cooperation between the local and regional level. Together with target-group-specific information, this can bring about a better understanding of flood risk and its link to inappropriate development, and thus emphasize the need for more suitable land uses in river catchment areas.

Strategic funding on a regional and national level, developed on the basis of the aforementioned visioning processes and regional objectives, can help compensate for imbalances between upstream communities and those further downstream, thereby supporting a pro-active and preventative approach to flood risk management. In parallel with this, regional competitions can promote the development of innovative ideas and concepts.

Regional planning, however, not only has to raise these issues higher up on its agenda, but must also coordinate efforts with water management authorities, which can provide the necessary data.

Ultimately, a fundamental shift and re-orientation in river management is urgently needed. An increased public debate about value judgements and general assumptions will need to challenge perceptions, for example, of the word “flooding”, which is instantly associated with risk, calamity and damage to lives and property. In reality, however, the cause of the calamity and damage is not the flooding itself, but the allocation of unsuitable uses in floodplains, thereby creating a conflict between the needs of the river and those of people and communities.

The question of how to minimize flood damage could thus initiate a debate about a new “riparian culture”. The real question here has to be: “How can we best develop our living environment with – not against – the river?” and within this we also have to take account of all possible climate change scenarios.

This discussion and shift in values could make a highly relevant contribution to fostering a more positive and pro-active approach to the development of river environments. With the EU Water Framework Directive coming into force, this is a good time to look at the river as an integrated system that is entitled to the space it needs.

6 StartClim2013.E: How and where will Austrian river systems respond to climate change? An interdisciplinary analysis of fish fauna and nutrients

Climate change and changes in land use have diverse effects on running water ecosystems. This study aims to demonstrate the combined effect of climate change and (changes in) land use on nutrient concentrations, water flows and fish fauna in Austrian streams and rivers. In Austria, many streams and small rivers belong to the so-called trout zone or the grayling zone, where the fish fauna is dominated by cold-water fish species (especially trout and grayling). The reduction of habitats for these fish species due to climate change will not only pose a threat to biodiversity, but may also lead to unexpected changes in the functioning of the whole riparian ecosystem.

Using a specific statistical tool (path analysis), the interrelationships between temperature, land use, streamflow and nitrite concentrations were quantified for a representative set of Austrian rivers and streams. Nitrite is an important intermediate product of the nitrogen cycle. Under normal conditions it will occur in running waters at very low concentrations only. Even slightly raised concentrations can be toxic to aquatic life. Thus, any increase in nitrite concentrations may limit the distribution of sensitive species.

In a second step, the occurrence of important fish species was linked to the environmental variables mentioned above, as well as land use and watercourse structure (logistic regression analysis). Based on these findings, scenarios were developed for mean flow rates and nitrite concentrations in summer, as well as for the occurrence of key fish species in 2050. Summer values were used, as summer is a critical time for cold-water-adapted fish species. To avoid uncertainties associated with the future development of summer runoff in rivers and streams with a hydraulic regime dominated by snowmelt or runoff from glaciers, the future scenarios were applied only to sections of rivers and streams below 700m amsl that are strongly influenced by rainfall (pluvial discharge regime).

Air temperature values derived for the emission scenario A1B were used for all scenarios. These air temperature conditions were combined with different scenarios for land use development, taking account of arable farming, extent of woodland/forest and extent of wetlands. For each scenario, two scenarios with an higher percentage of wetland in the catchment area were established and set in contrast to the scenario with a “realistic” estimate for the share of wetland, to investigate the mitigation potential of wetlands.

In scenario A1B, mean summer temperatures are likely to increase approximately 3–4°C with extremes of 5°C. These temperatures are high enough to exclude cold-water species from many stretches of river.

In addition to the direct effects, a number of notable indirect effects are also likely to affect the Alpine fish fauna. for example, higher temperatures will make a larger proportion of catchment areas at medium altitudes (up to 700m) available for agriculture. According to the data gathered, a higher share of arable land use will lead to considerably reduced flow rates (and higher nitrite concentrations) in summer, especially in mid-sized and larger rivers. Lower water levels offer less habitat for aquatic life. Larger animals such as fish are likely to be strongly affected by this. Lower volumes of water also heat up faster than large volumes of water. The dissolved oxygen content will drop in warmer water while higher temperatures will also increase the metabolism of riverine biota, thereby further decreasing oxygen levels in the water. Fish species that are adapted to an oxygen-rich environment are likely to be most affected by these indirect effects, which includes the above-mentioned cold-water species.

The expected occurrence of seven fish species (four typical representatives of the trout and grayling zone, two representatives of the barbel zone and the top-mouth gudgeon, a non-native fish species likely to have a negative effect on native fish fauna) could be predicted using the environmental parameters mentioned above. The analysis showed that temperature and flow rates in summer had the strongest impact on fish population. Brown trout and rainbow trout, both species associated with the upper headwaters, prefer cooler temperatures, while the occurrence of barbel, nase carp and top-mouth gudgeon was favoured by warmer temperatures. The higher the flow rates in summer, the higher the potential occurrence of three out of the seven fish species. Only the top-mouth gudgeon prefers lower flow rates. Interestingly, nitrite concentrations affected three fish species negatively; for the grayling, nitrite concentration was the most important environmental factor.

The scenarios revealed that cold-water species can be expected to face a considerable reduction in habitat, while species that are adapted to higher temperatures should be able to expand their range as a result of higher temperatures. In the case of non-native species, such as the top-mouth gudgeon, this is likely to impact on smaller native species.

Strategic land use planning will need to consider the effects of different land uses on water levels in summer, while water management authorities will need to take measures to address the expected rise in nitrite concentrations in summer.

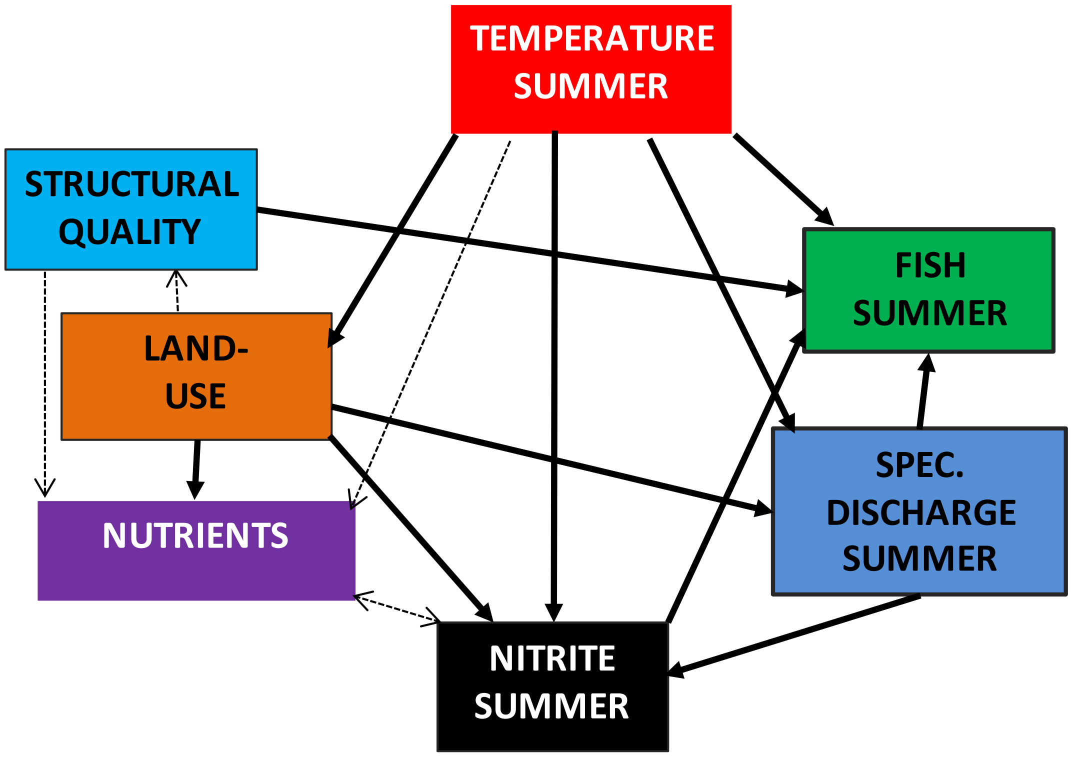

Fig. 8: Schematic representation of observed and expected interrelations. Bold arrows: relationships verified by this study (methods used: path analysis, logistic regression analysis), dotted arrows: assumed relationships not investigated in this study. Key:
Temperature – mean air temperature, structural quality – proportion of river stretch without impoundment / water abstraction, respectively, quality of in-stream river morphology, land use – share of agriculture (woodland / wetland in the catchment), nitrite – Median concentration, spec. discharge - discharge per km² discharge area, fish – occurrence of 7 fish species, summer – June, July, August, September

7 StartClim2013.F: GIAClim – Gender Impact Assessment in the context of climate change adaptation and natural hazards

Climate change is not gender-neutral. Women and men are affected in different ways by natural disasters – which are likely to increase as a result of climate change (e.g. Rathgeber 2005, Weber 2005; Mehta 2007). Furthermore, socio-economic status, ethnic background, age and other aspects influence individual risk (International Federation of Red Cross and Red Crescent Societies 2006: 8). Policies aimed at climate change mitigation, as well as adaptation strategies and measures, impact differently on women and men, depending on life stage and situation, social and cultural background.

Based on the example of a debris flow in 2012 in St. Lorenzen, a village in the municipality of Trieben in the Palten Valley in Styria (see Fig. 9 and Fig. 10), the research team tested methods, tools and approaches for a Gender Impact Assessment in the context of climate change and natural hazards. The project focuses on the gender dimensions of natural hazards that, as a result of climate change, are likely to increase in frequency and intensity in some regions of Austria.

Socio-economic, social, cultural, environmental, spatial, physical and psychological circumstances and parameters influence people's ability to handle, avoid and cope with the effects of climate change and natural disasters (e.g. UNISDR, UNDP, IUCN 2009, Le Masson 2013). These individual differences can have positive or negative impacts on the vulnerability of those affected (BMLFUW 2013). For the purposes of this project, the term "gender" is defined in a wider sense as "gender+" and includes the differences between individuals and groups in terms of their life stage and situation, social and cultural background (Quing 2011).

The results of the study show that as yet there is little awareness among the population as well as within emergency response teams of group- and gender-specific aspects, but that raising awareness of gender- and group-specific needs and requirements could improve emergency response and disaster relief efforts. It also showed that knowledge transfer between all levels of decision-making is not as effective as it could and should be.

The analysis also revealed that people without strong local social networks are likely to be worse affected by the impacts of a natural disaster. The objective of disaster relief should not be to help everybody in the same way, but to help everyone equally *well*. However, this requires a differentiated approach and deeper knowledge of the different requirements of the various groups identified. Such an approach would allow all groups to participate equally in decision-making and strengthen the ability of individuals and communities to help themselves.

The results of the case study and a literature review inform a Gender Impact Assessment for natural hazards in Austria as well as practical tools for regional and local governments and practitioners in disaster management. For example, on the local and regional level, a new tool for a gender-sensitive analysis of measures concerning technical projects or organizational processes has been developed. This tool is called Gender Analysis for Natural Disasters (GAND) and combines different analysis approaches: 4R-methode, Gender Analysis Matrix (Parker 1993) and Capacities and Vulnerabilities Framework (UNISDR, UNDP and IRP 2010). It comprises five steps covering an "analysis – measures – evaluation" loop described in the following table:

Tab. 2: The five steps of GAND (Gender Analysis of Natural Disasters)

Gender Analysis of Natural Disasters (GAND)		
1	**Objectives**	Participation
2	**Description of natural hazard/catastrophe, risks** **Gender-specific description of socio-economic, demographic situation, structure of organisa-tions, analysis of the environmental circumstances** **Description of the relevant planning instruments, laws, policies, strategies, disaster manage-ment plans**	
3	**Gender-sensitive analysis of** **Strenghts and Weeknesses - Vulnerability and Competence** built environment and land use socio-economic and demographic situation physical and mental health, perception of safety and risks planning instruments, policies, laws, strategies, participation and decision making knowledge transfers competences and capacity communication, information, media	participation
4	**Measures and instruments for a gender-sensitive risk and disaster management**	participation
5	**Gender-sensitive evaluation of the implementation of measures and instruments**	

Furthermore, the study identified the need for further research, e.g. the development of more and precise indicators for the gender-sensitive management of natural disasters, a social area analysis for areas in Austria affected by natural disasters and other aspects of climate change, as well as the improvement of knowledge transfer to build local resilience and improve self-reliance.

Fig. 9: The village St. Lorenzen in the Palten valley after the debris flow in July 2012 (Janu et al., 2012)

Fig. 10: Women and men clearing debris after the debris flow in St. Lorenzen (IAN)

8 StartClim2013.G: Validation of the applicability of the SIMAGRIO-W wireworm prognosis model, based on soil temperature and moisture measurements, in Eastern Austrian agriculture

Wireworms are the larvae of the click beetle (*Coleoptera*, Fam. *Elateridae*). They live in the soil for several years, causing substantial damage by feeding on the subterranean parts of crop plants (Fig. 11). Several studies have shown that high soil temperatures can speed up wireworm development, leading to a rapid rise in wireworm population density under favourable conditions. Rising mean temperatures as a result of climate change are therefore likely to increase damage to crops from indigenous thermophile wireworm species, while new species from the Mediterranean may migrate further north, as already observed in Germany.

To be able to respond to this increasing wireworm pressure, farmers will need a practical tool to analyse wireworm damage risk, enabling them to make informed and timely decisions about cultivation, management and control measures. For example, cultivation of sensitive crops should be avoided, where possible, on fields with high wireworm density. Furthermore, in practical studies, crop rotations with a high proportion of summer crops and the associated intensive soil cultivation in spring, have proven to be effective in reducing wireworm populations.

Both soil temperature and soil moisture have a decisive influence on larval movement within the soil column. Whenever conditions are favourable, wireworms will be active nearer the surface, where they cause the most damage to crops. If the topsoil is too hot and dry or too cold and moist, they move into deeper soil regions, where conditions are more favourable for them. Based on these parameters (i.e. soil temperature, soil moisture and soil type), the wireworm prognosis model SIMAGRIO-W (SIMulation of the larvae of AGRIOtes Wireworms, ZEPP), developed in Germany, calculates the percentage of a given wireworm population that is located in the upper 15cm of the soil column. It should be noted, however, that it provides no information on the actual size of the wireworm population. A first validation of the model in the German federal state of Rhineland-Palatinate showed more than 80% correct predictions. At the test sites in Germany, the model was able to efficiently predict the presence of a significant proportion of the wireworm population (>30%) in the upper 15cm of the soil.

SIMAGRIO-W thereby provides information on the potential damage risk in a field at a given time, since the most vulnerable parts of the crop plants are concentrated in the upper region of the soil (= damaging zone). For example, if high wireworm activity in the damaging zone is expected, the cultivation of maize can be delayed to avoid seeds and young plants being exposed to wireworm damage. Similarly, in potato fields, the harvest can be brought forward to prevent excessive damage.

Furthermore, control measures, such as intensive soil cultivation, can thus be conducted when they are most effective – namely when the larvae are near the surface.

In order to estimate the actual risk in a given field, it is necessary to measure wireworm density and species composition using wireworm bait traps. With the help of the SIMAGRIO-W predictions, bait traps can be installed during periods when high wireworm activity is anticipated below the surface, and therefore within range of the traps. This guarantees that a higher proportion of the wireworm population is caught and therefore leads to a more representative density measurement.

In this study, SIMAGRIO-W was tested under practical conditions in Eastern Austria. At four sites in the regions Bruck/Leitha, Traiskirchen and Essling (Vienna), wireworm densities in the upper 15cm of the soil (= damaging zone) were measured between mid-July and the end of October 2013 using wireworm bait traps (Fig. 12). At each site, soil temperature and soil moisture at 15cm and 80cm soil depth were recorded with data loggers over the whole study period. Soil types at the test sites were determined using grain size analysis. Based on the measured soil temperatures, moisture levels and soil types, predicted percentages of the wireworm population in the damaging zone were calculated for each site and trapping period. The simulated predictions were then compared against actual measured wireworm activity at each test site to assess the applicability of the SIMAGRIO-W model in Eastern Austria.

The validation of SIMARIO-W's usefulness for Eastern Austrian agriculture resulted in a low overall hit rate of 54%. At two sites, it achieved an accuracy of about 71%, followed by 54% and 14% at the other sites. Activity peaks were predicted accurately in only a few cases (Fig. 13).

The weak hit rate was caused primarily by the fact that wireworm populations at the Eastern Austrian study sites have different thermal preferences than the model assumes. They showed activity peaks in the damaging zone at soil temperatures of up to 26°C. SIMAGRIO-W, however, works on the assumption that this would be too hot for the larvae. The current version of the model assumes wireworm peak activity at about 11°C.

This discrepancy may be explained by differences in temperature optimum and tolerance between the *Agriotes* species dominant in Eastern Austria (e.g. A. *ustulatus* and A. *brevis*) and in western Germany (e.g. A. *obscurus*), where the model has been developed and calibrated.

If the thermal preferences of regionally dominant wireworm species are taken into account, SIMAGRIO-W should be able to make a valuable contribution to the prevention of wireworm damage in Eastern Austrian agriculture. Consequently, further research aimed at adapting the model to regional conditions is strongly recommended.

Fig. 11: Wireworm (*Agriotes sp*., orange) on the roots of a young maize plant.

Fig. 12: A line of wireworm bait traps and two data loggers (in the foreground) in a maize field near Bruck/Leitha. The traps were installed in a large area of bare soil caused by severe wireworm damage.

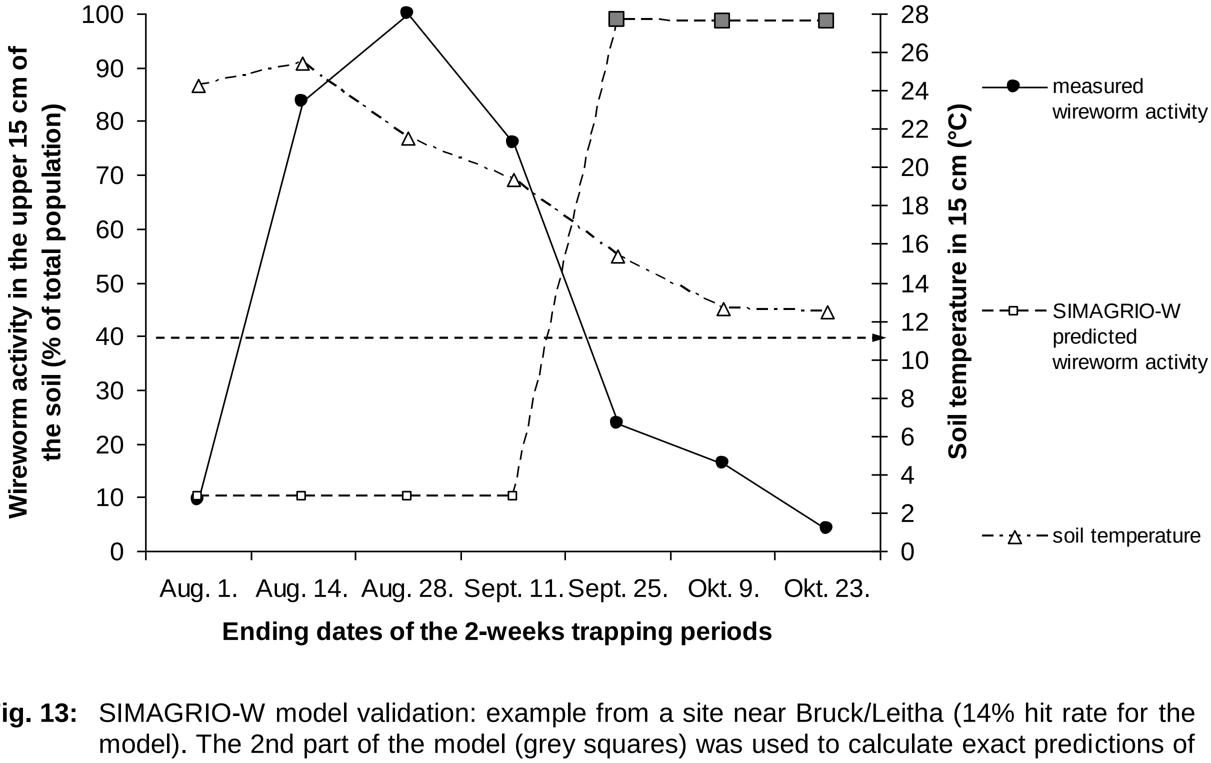

Fig. 13: SIMAGRIO-W model validation: example from a site near Bruck/Leitha (14% hit rate for the model). The 2nd part of the model (grey squares) was used to calculate exact predictions of wireworm percentages in the upper 15cm of the soil during trapping periods where the 1st part of SIMAGRIO-W predicted a wireworm activity of >10% for at least one day. Otherwise, an activity ≤10% was assumed. If both measured and predicted wireworm activity was above or below the validation threshold of 30% of the total population, the trapping period was counted as a hit for the model. The dashed arrow marks the temperature optimum for wireworm activity according to SIMAGRIO-W. At this site, nearly all trapped larvae were identified as *Agriotes ustulatus*.

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10 List of Figures and Tables

Figures

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Annex

The following projects were part of StartClim2003 to StartClim2012. All reports can be found on the StartClim2013-CD-ROM or downloaded from the StartClim webpage (www.startclim.at).

Subprojects of StartClim2003

StartClim.1: Quality control and statistical characteristics of selected climate parameters on the basis of daily values in the face of extreme value analysis
Central Institute of Meteorology and Geodynamics
Wolfgang Schöner, Ingeborg Auer, Reinhard Böhm, Sabina Thaler

StartClim.2: Analysis of the representativeness of a data collected over a span of fifty years for the description of the variability of climatic extremes
Central Institute of Meteorology and Geodynamics
Ingeborg Auer, Reinhard Böhm, Eva Korus, Wolfgang Schöner

StartClim.3a: Extreme events: documentation of hazardous events in Austria such as rock avalanches, floods, debris flows, landslides, and avalanches
Institute of Forest and Mountain-Risk Engineering, BOKU
Dieter Rickenmann, Egon Ganahl

StartClim.3b: Documentation of the impact of extreme weather events on agricultural production ARC Seibersdorf research: Gerhard Soja, Anna-Maria Soja

StartClim.3c: Meteorological extreme event data information system for the eastern Alpine region - MEDEA
Federal Environment Agency, Martin König, Herbert Schentz, Johann Weigl
IIASA, Mathias Jonas, Tatiana Ermolieva

StartClim.4: Development of a method to predict the occurrence of extreme events from large-scale meteorological fields
Institute of Meteorology and Physics, BOKU Andreas Frank, Petra Seibert

StartClim.5: Testing statistical downscaling techniques for their applicability to extreme events in Austria
Institute of Meteorology and Physics, BOKU -
Herbert Formayer, Christoph Matulla, Patrick Haas
GKSS Forschungszentrum Geesthacht, Nikolaus Groll

StartClim.6: Adaptation strategies for economic sectors affected heavily by extreme weather events: economic evaluation and policy options
Austrian Humans Dimensions Programme (HDP-A)
Department of Economics, Karl-Franzens-Universität Graz
Karl Steininger, Christian Steinreiber, Constanze Binder, Erik Schaffer
Eva Tusini, Evelyne Wiesinger

StartClim.7: Changes in the social metabolism due to the 2002-flooding in Austria: case study of an affected community
Institute of Interdisciplinary Studies of Austrian Universities (IFF)
Willi Haas, Clemens Grünbühel, Brigitt Bodingbauer

StartClim.8: Risk-management and public prosperity in the face of extreme weather events: What is the optimal mix of private insurance, public risk pooling and alternative transfer mechanisms
Department of Economics, Karl-Franzens-Universität Graz
Walter Hyll, Nadja Vetters, Franz Prettenthaler

StartClim.9: Summer 2002 floods in Austria: damage account data pool
Centre of Natural Hazards and Risk Management (ZENAR),
BOKU - University of Natural Resources and Applied Life Sciences
Helmut Habersack, Helmut Fuchs

StartClim.10: Economic aspects of the 2002 floodings: data analysis, asset accounts and macroeconomic effects
Austrian Institute of Economic Research (WIFO)
Daniela Kletzan, Angela Köppl, Kurt Kratena

StartClim.11: Communication at the interface science - education
Institute of Meteorology and Physics,
BOKU - University of Natural Resources and Applied Life Sciences
Ingeborg Schwarzl
Institute of Interdisciplinary Studies of Austrian Universities (IFF)
Willi Haas

StartClim.12: Developing an innovative approach for the analysis of the August 2002 flood event in comparison with similar extreme events in recent years
Department of Meteorology and Geophysics, University of Vienna
Simon Tschannett, Barbara Chimani, Reinhold Steinacker

StartClim.13: High-resolution precipitation analysis
Department of Meteorology and Geophysics, University of Vienna
Stefan Schneider, Bodo Ahrens, Reinhold Steinacker, Alexander Beck

StartClim.14: Performance of meteorological forecast models during the August 2002 floods Central Institute of Meteorology and Geodynamics
Thomas Haiden, Alexander Kann

StartClim.C: Design of a long term climate/climate-impact research programme for Austria Institute of Meteorology and Physics, BOKU:
Helga Kromp-Kolb, Andreas Türk

StartClim. Reference database:
Implementation of a comprehensive literature database on climate and climate impact research as a generally accessible basis for future climate research activities
Institute of Meteorology and Physics,
University of Natural Resources and Applied Life Sciences
Patrick Haas

Subprojects of StartClim2004

StartClim2004.A: Analysis of heat and drought periods in Austria: extension of the daily StartClim data record by the element vapour pressure
Central Institute of Meteorology and Geodynamics
Ingeborg Auer, Eva Korus, Reinhard Böhm, Wolfgang Schöner

StartClim2004.B: Investigation of regional climate change scenarios with respect to heat waves and dry spells in Austria
Institute of Meteorology, BOKU: Herbert Formayer, Petra Seibert, Andreas Frank, Christoph Matulla, Patrick Haas

StartClim2004.C: Analysis of the impact of the drought in 2003 on agriculture in Austria – comparison of different methods
ARC Seibersdorf research: Gerhard Soja, Anna-Maria Soja
Institute of Meteorology, BOKU: Josef Eitzinger, Grzegorz Gruszczynski, Mirek Trnka, Gerhard Kubu, Herbert Formayer
Institute of Surveying, Remote Sensing and Land Information, BOKU
Werner Schneider, Franz Suppan, Tatjana Koukal

StartClim2004.F: Continuation and further development of the MEDEA event data base
Federal Environment Agency: Martin König, Herbert Schentz, Katharina Schleidt
IIASA: Matthias Jonas, Tatiana Ermolieva

StartClim2004.G: "Is there a relation between heat and productivity?" A project at the interface between science and education
Institute of Meteorology, BOKU
Ingeborg Schwarzl, Elisabeth Lang, Erich Mursch-Radlgruber

Subprojects of StartClim2005

StartClim2005.A1a: Impacts of temperature on mortality and morbidity in Vienna
Medical University of Vienna, Centre for Public Health, Institute of Environmental Hygiene
Hanns Moshammer, Hans-Peter Hutter
Institute of Meteorology, BOKU
Andreas Frank, Thomas Gerersdorfer
Austrian Federal Institute of Health Care
Anton Hlava, Günter Sprinzl
Statistics Austria, Barbara Leitner

StartClim2005.A1b: Nocturnal cooling under a changing climate
Institute of Meteorology, BOKU
Thomas Gerersdorfer, Andreas Frank, Herbert Formayer, Patrick Haas
Medical University of Vienna, Centre for Public Health, Institute of Environmental Hygiene
Hanns Moshammer
Statistics Austria, Barbara Leitner

StartClim2005.A4: Impacts of meteorological extreme events on safety of drinking water supply in Austria
Institute of Sanitary Engineering and Water Pollution Control, BOKU
Reinhard Perfler, Mario Unterwainig
Institute of Meteorology, BOKU
Herbert Formayer

StartClim2005.C2: Studies on the distribution of tularaemia under the aspect of climate change
Gesellschaft für Wildtier und Lebensraum – Greßmann & Deutz OEG
Armin Deutz
HBLFA Raumberg Gumpenstein, Agricultural Research and Education Centre
Thomas Guggenberger

StartClim2005.C3a: Impacts of climate change on agricultural pests and antagonists in organic farming in Eastern Austria
Bio Forschung Austria
Bernhard Kromp, Eva Maria Grünbacher, Patrick Hann
Institute of Meteorology, BOKU
Herbert Formayer,

StartClim2005.C3b: Risk analysis of the establishment of the western flower thrips (*Frankliniella occidentalis*) under outdoor conditions in Austria as a result of the climate change
The Austrian Agency für Health and Food Safety, AGES
Andreas Kahrer
Institute of Meteorology, BOKU
Herbert Formayer,

StartClim2005.C5: An allergenic neophyte and its potential spread in Austria – range dynamics of ragweed (*Ambrosia artemisiifolia*) under influence of climate change
VINCA, Vienna Institute for Nature Conservation & Analysis
Ingrid Kleinbauer, Stefan Dullinger
Federal Environment Agency
Franz Essl, Johannes Peterseil

StartClim2005.F: GIS-sustained simulation of diminishing habitats of snow grouse, black grouse, chamois and capricorn under conditions of global warming and heightening forest limits
Joanneum Research
Heinz Gallaun, Jakob Schaumberger, Mathias Schardt
HBLFA Raumberg-Gumpenstein
Thomas Guggenberger, Andreas Schaumberger, Johann Gasteiner
Gesellschaft für Wildtier und Lebensraum - Greßmann & Deutz OEG
Armin Deutz, Gunter Greßmann

Subprojects of StartClim2006

StartClim2006.A: Particulate matter and climate change – are there connections between them in north-eastern Austria?
Institute of Meteorology, BOKU: Bernd C. Krüger, Irene Schicker, Herbert Formayer
Medical University of Vienna, Centre for Public Health, Institute of Environmental Hygiene: Hanns Moshammer

StartClim2006.B: Risk Profile for the autochthonous occurrence of Leishmania infections in Austria
Medical University of Vienna: Horst Aspöck, Julia Walchnik
Institute of Meteorology, BOKU: Thomas Gerersdorfer, Herbert Formayer

StartClim2006.C: Effects of climate change on the dispersion of white grub damages in the Austrian grassland

Bio Forschung Austria
Eva Maria Grünbacher, Patrick Hann, Claus Trska, Bernhard Kromp
Institute of Meteorology, BOKU: Herbert Formayer

StartClim2006.D1: Sensitivity of Austrian summer tourism to climate change
Institut für touristische Raumplanung: Volker Fleischhacker
Institute of Meteorology, BOKU: Herbert Formayer

StartClim2006.D2: Effects of climate change on the climatic potential of tourism
Institute of Meteorology, University of Freiburg
Andreas Matzarakis, Christina Endler, Robert Neumcke
Central Institute of Meteorology and Geodynamics
Elisabeth Koch, Ernest Rudel

StartClim2006.D3: See-Vision: influence of climate change-induced fluctuation of water level in Lake Neusiedl on the perception and behaviour of visitors and locals
Institute of Landscape Development, Recreation and Conservation Planning, BOKU
Ulrike Pröbstl, Alexandra Jiricka, Thomas Schauppenlehner
Simon Fraser University, Burnaby, Canada
Wolfgang Haider

StartClim2006.F: Climate change impacts on energy use for space heating and cooling in Austria
Institute of Technology and Regional Policy, Joanneum Research (1);
Wegener Center for Climate and Global Change, University of Graz (2);
Institute for Geophysics, Astrophysics and Meteorology, University of Graz (3);
Institute for Meteorology and Geophysics, University of Vienna (4);
Institute of Energy Research, Joanneum Research (5)
Franz Prettenthaler[1,2], Andreas Gobiet[2,3],
Clemens Habsburg-Lothringen[1], Reinhold Steinacker[4],
Christoph Töglhofer[2], Andreas Türk [2,5]

Subprojects of StartClim2007

StartClim2007.A: Enlargement and completion of the StartClim dataset for the element daily snow depth. Update of the already existing StartClim datasets (air temperature, precipitation and vapour pressure) until April 2007
Central Institute of Meteorology and Geodynamics: Ingeborg Auer,
Anita Jurković, Reinhard Böhm, Wolfgang Schöner, Wolfgang Lipa

StartClim2007.B: Health risks for the Austrian population due to the depletion of stratospheric ozone
Institute of Meteorology, University of Natural Resources and Applied Life Sciences, Vienna: Stana Simic
Institute of Medical Physics and Biostatistics, University of Veterinary Medicine Vienna: Alois W. Schmalwieser
Medical University of Vienna, Centre for Public Health, Institute of Environmental Hygiene: Hanns Moshammer

StartClim2007.C: Adaptations of insect pests to climate change in crop production of eastern Austria: conception of a long-term monitoring system
Bio Forschung Austria: Eva-Maria Grünbacher, Patrick Hann, Bernhard Kromp
Institute of Meteorology, University of Natural Resources and Applied Life Sciences, Vienna: Herbert Formayer

StartClim2007.D: Consequence of the climate-induced upwards shift of the timberline on the release of greenhouse gases - dynamics of soil organic matter
Federal Forest Office: Robert Jandl, Andreas Schindlbacher,
Sophie Zechmeister-Boltenstern, Michael Pfeffer
Department of Forest and Soil Sciences, University of Natural Resources and Applied Life Sciences, Vienna:
Klaus Katzensteiner
Federal Environment Agency: Sabine Göttlicher
University of Vienna: Hannah Katzensteiner
Tiroler Landesforstdirektion: Dieter Stöhr

StartClim2007.E: Global change and its effect on runoff behaviour of glacierised basins with regard to reservoir power stations
Institute of Meteorology and Geophysics, University Innsbruck:
Michael Kuhn, Marc Olefs, Andrea Fischer

StartClim2007.F: ALSO WIKI – Alpine summer tourism in Austria and the potential effects of climate change
Austrian Institute for Regional Studies and Spatial Planning: Cornelia Krajasits, Gregori Stanzer, Adolf Anderl, Wolfgang Neugebauer, Iris Wach
Central Institute of Meteorology and Geodynamics
Christine Kroisleitner, Wolfgang Schöner

StartClim2007.G: Integrated modelling of the economy under climate change in application of the STERN report (STERN.AT)
Wegener Centre for Climate and Global Change, University of Graz:
Olivia Koland, Karl Steininger, Andreas Gobiet, Georg Heinrich, Claudia Kettner, Alexandra Pack, Matthias Themeßl, Christoph Töglhofer, Andreas Türk, Thomas Trink
Joanneum Research, Institut für Technologie- und Regionalpolitik:
Raimund Kurzmann
University of Natural Resources and Applied Life Sciences, Vienna: Erwin Schmid

Subprojects of StartClim2008

StartClim2008.A: Impacts of adaptation measures on the acute mortality risk due to extreme temperature in Vienna
Institute of Environmental Hygiene, Centre for Public Health, MUW: Hanns Moshammer, Hans-Peter Hutter
Institute of Meteorology, BOKU: Thomas Gerersdorfer

StartClim2008.B: Which adaptations of soil erosion protection measures can be recommended for expected climate change impacts?
Institute of Hydraulics and Rural Water Management, BOKU: Andreas Klik
Institute of Meteorology, BOKU: Josef Eitzinger
Institute of Agronomy and Plant Breeding, BOKU: Peter Liebhard

StartClim2008.C: Practical testing of the monitoring concept "Adaptations of insect pests to climate change in crop production of eastern Austria" by investigating the distribution of current cutworm (*Agrotis segetum, Schiff.; Fam. Noctuidae*) damage as a function of site-related and climatic factors
Bio Forschung Austria: Patrick Hann, Claus Trska, Eva Maria Frauenschuh, Bernhard Kromp

StartClim2008.D: Organic agriculture in the mountains of Tyrol—contributions to mitigating climate change and adaptation strategies
Division of Organic Farming, BOKU: Michael Dorninger, Bernhard Freyer

StartClim2008.E: Development and economic valuation of landscape structures to decrease evapotranspiration on agricultural acres with account taken of climate change and biomass production
Institute of Landscape Development, Recreation and Conservation Planning, BOKU: Christiane Brandenburg, Bernhard Ferner, Sonja Völler, Brigitte Allex
Institute of Meteorology, BOKU: Josef Eitzinger, Thomas Gerersdorfer
Division of Organic Farming, BOKU: Bernhard Freyer, Andreas Surböck, Agnes Schweinzer, Markus Heinzinger
Institute of Agricultural and Forestry Economics, BOKU: Enno Bahrs

StartClim2008.F: Perception and evaluation of natural hazards as a consequence of glacier retreat and permafrost degradation in tourism destinations—a case study in the Tux Valley (Zillertaler Alps, Austria)
Institute of Landscape Development, Recreation and Conservation Planning, BOKU: Ulrike Pröbstl
University of Regensburg, University Eichstätt-Ingolstadt: Bodo Damm

StartClim2008.G: Adaptation of forest soils to a changing climate
Federal Research and Training Centre for Forests, Natural Hazards and Landscape: Barbara Kitzler, Verena Stingl, Sophie Zechmeister-Boltenstern
Institute of Meteorology and Climate-Research – Atmospheric Environmental Research, Garmisch: Arjan De Brujin, Ralf Kiese, Klaus Butterbach-Bahl

Subprojects of StartClim2009

StartClim2009.A: Vegetation change according to different climate and management conditions in Austrian mountain grassland – a case study on Styrian mountain grasslands
Institute of Botany, BOKU: Gabriele Bassler, Gerhard Karrer,
Institute of Meteorology, BOKU: Herbert Formayer
LFZ-Raumberg-Gumpenstein: Andreas Schaumberger, Andreas Bohner, Walter Starz
Bio Ernte Steiermark: Wolfgang Angeringer

StartClim2009.B: Climate-growth response of Norway spruce provenances in the Alpine region – an opportunity for adaption of the Austrian forestry
Federal Research and Training Centre for Forests, Natural Hazards and Landscape: Silvio Schüler, Stefan Kapeller,
Central Institute of Meteorology and Geodynamics: Johann Hiebl

StartClim2009.C: Analysis of vulnerability and adaptation to climate change in the Wienerwald biosphere reserve
Institute of Silviculture, BOKU: Stefan Schörghuber, Werner Rammer, Rupert Seidl, Manfred J. Lexer

StartClim2009.D: Humus assays as a practical tool for farmers to support carbon sequestration in agriculture
Bio Forschung Austria: Wilfried Hartl, Eva Erhart

StartClim2009.E: Adapting office buildings to climate change: optimisation of thermal comfort
Danube University Krems: Tania Berger, Peter Pundy

StartClim2009.F: AlpinRiskGP - estimation of present and future risk potential for Alpine tourists and infrastructure caused by glacier retreat and permafrost changes in the Grossglockner-Pasterze glacier area (Hohe Tauern, Austria)
Geography and Regional Science, Karl-Franzens-University Graz: Gerhard Karl Lieb, Katharina Kern, Gernot Seier,
Andreas Kellerer-Pirklbauer-Eulenstein, Ulrich Strasser

Subprojects of StartClim2010

StartCim2010.A: Fields of action and responsible actors for climate change adaptation of public parks in cities
Institute of Landscape Development, Recreation and Conservation Planning (ILEN), BOKU: Stephanie Drlik, Andreas Muhar

StartClim2010.B: Recommendations for an adaptation of urban open and green spaces in Austrian cities and city regions
PlanSinn GmbH, Office for Planning and Communication: Erik Meinharter
Federal Environment Agency: Maria Balas

StartClim2010.C: The social costs of adaptation: approaches to an evaluation of adaptation options (SALDO)
Wegener Center for Climate and Global Change, University Graz:
Birgit Bednar-Friedl, Olivia Koland, Janine Raab
Federal Environment Agency: Martin König

StartClim2010.D: Integrated precautionary and adaptation measures for the Marchfeld region
Institute for Sustainable Economic Development, BOKU: Christine Heumesser, Mathias Kirchner, Erwin Schmid, Franziska Strauss

StartClim2010.E: Ecological and silvicultural characteristics of European larch (Larix decidua Mill.) – consequences for forest management in Austria in consideration of climate change
Institute of Silviculture, BOKU: Eduard Hochbichler, Gabriele Wolfslehner, Roland Koeck, F. Arbeiter,
Federal Research and Training Centre for Forests, Natural Hazards and Landscape: Herfried Steiner, Georg Frank
Institute of Meteorology, BOKU: Herbert Formayer

Startclim2010.F: Hot town, summer in the city – effects of hot days on recreational and leisure behaviour and sightseeing programmes of city tourists as exemplified by the case of Vienna
Institute of Landscape Development, Recreation and Conservation Planning (ILEN), BOKU: Christiane Brandenburg, Brigitte Allex, Ursula Liebl, Christina Czachs
Institute of Meteorology, BOKU: Thomas Gerersdorfer

StartClim2010.G: Knowledge-based platform to optimise operations strategies in handling natural hazards
Austrian Red Cross: Jürgen Högl, Clemens Liehr, Gerry Foitik
Institute of Production and Logistics, BOKU: Manfred Gronalt, Magdalena Schweiger, Patrick Hirsch

Subprojects of StartClim2011

StartCim2011.A: Climatic influence on voltinism and spread of the spruce bark beetle, Ips typographus, in alpine areas
Institute of Forest Entomology, Forest Pathology & Forest Protection, BOKU: Axel Schopf, Emma Blackwell, Veronika Wimmer

StartClim2011.B: Analyzing Austria's forest disturbance regime as basis for the development of climate change adaptation strategies
Institute of Silviculture, BOKU: Rupert Seidl, Dominik Thom
Institute of Forest Protection, Federal Research and Training Center for Forests, Natural Hazards, and Landscape (BFW): Hannes Krehan, Gottfried Steyrer

StartClim2011.C: Effects of soil drying on the transpiration of Austrian tree species
University of Innsbruck: Georg Wohlfahrt, Stefan Mayr, Christoph Irschick, Sabrina Obwegeser, Petra Schattanek, Teresa Weber, Dorian Hammerl, Regina Penz

StartClim2011.D: Adapting Austrian forestry to climate change: Assessing the drought tolerance of Austria's autochthonous tree species
Institute of Botany, BOKU: Gerhard Karrer, Gabriele Bassler
Institute of Forest Ecology, BOKU: Helmut Schume, Bradley Matthews
Vienna Institute for Nature Conservation and Analyis, V.I.N.C.A: Wolfgang Willner

Subprojects of StartClim2012

StartClim2012.A: Cover crops as a source or sink of soil greenhouse gas emissions?
Division of Agronomy, Department of Crop Sciences, BOKU: Gernot Bodner, Andreas Klik, Sophie Zechmeister-Boltenstern

StartClim2012.B: Effects of climate change on soil functions: metadata analysis
Federal Research and Training Centre for Forests, Natural Hazards, and Landscape (BFW): Michael Englisch, Barbara Kitzler, Kerstin Michel, Michael Tatzber
Federal Agency for Water Management, Institute for Land & Water Management Research (BAW-IKT): Thomas Bauer, Peter Strauss
Austrian Agency for Health and Food Safety (AGES): Andreas Baumgarten, Hans-Peter Haslmayr
Federal Environment Agency: Alexandra Freudenschuß

StartClim2012.C: Disturbance of forest stands and humus loss
Institute of Forest Ecology, BOKU: Douglas Godbold, Mathias Mayer, Boris Rewald

StartClim2012.D: To count with and on wood: adaptations of tools and data (German: Holz BZR)
Kompetenzzentrum Holz GmbH: Tobias Stern, Franziska Hesser, Georg Winner, Sebastian Koch
Institute of Marketing and Innovation, BOKU: Leyla Jazayeri-Thomas, Verena Aspalter, Martin Braun, Wolfgang Huber, Peter Schwarzbauer
Institute of Wood Science and Technology, BOKU: Robert Stingl, Marie Louise Zukal, Alfred Teischinger
Federal Environment Agency: Peter Weiss, Alexandra Freudenschuß

StartClim2012.E: Snow line climatology within the Alpine region, derived from re-analysis data
Institute of Meteorology, BOKU: Herbert Formayer, Imran Nadeem

StartClim2012.F: Values as performance indicators: a path towards a proactive climate protection
Centre for Global Change and Sustainability, BOKU: Maria Miguel Ribeiro, Julia Buchebner