StartClim2008

Adaptation to Climate Change in Austria

Final Report

July 2009

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Final Report

Project Leader

Institute of Meteorology
Department of Water-Atmosphere-Environment
BOKU - University of Natural Resources and Applied 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 Health
Austrian Federal Ministry of Economy, Family and Youth
Austrian Federal Ministry of Science and Research
Austrian Federal Forests
Österreichische Nationalbank
Austrian Hail Insurance
Federal Environment Agency
Verbund AHP

Administrative Coordination
Federal Environment Agency

Vienna, July 2009

StartClim2008
"Adaptation to Climate Change in Austria"

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Vienna, July 2009

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Abstract

Alongside climate protection, adaptation to climate change is gaining in importance. As the fourth IPCC report demonstrates, the impact of climate change is evident, and is likely to increase in future, since a certain rate of climate change is now inevitable despite massive climate protection measures. StartClim therefore deals with the subject of adaptation to climate change as a way of contributing to the development of an Austrian strategy in this regard.

Little attention has been paid to date to soils and their role in climate change, despite the fact that they are important carbon pools and that aerobic soils are the only known biological sink for atmospheric methane. Soils are also considered to be the major source of nitrous oxide (55–65%) and methane (15–45%, in wetlands). Because of the complexity of the processes involved (mineralisation, nitrification, denitrification, methane oxidation and reduction) it is still difficult to estimate the regional and global source and sink strength of soil-related greenhouse gas emissions like carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O).

As microbial activity is very sensitive to temperature and moisture, soils may become nitrogen and carbon sources if temperature increases or precipitation patterns (drought, flooding, etc.) change. Furthermore, increases in nitrogen deposition or land-use changes may effect soil process rates and thus lead to a change in the source and sink strength of soils.

Because of the high spatial and temporal variability of microbial processes (“hot spots” and “hot moments”) in soils, and the need for reliable GHG emission estimates, field and laboratory studies have to be supported by process-oriented simulation models.

Data from several research projects (over ten years of data from three different forest sites (Achenkirch (Tyrol), Schottenwald und Klausenleopoldsdorf (Wienerwald)) were used to test, adapt and improve the MOBILE-DNDC2 process-oriented ecosystem model to simulate nitrogen and carbon cycles in temperate forests. The model was validated using data available from heated soil plots.

The temperature in Austria has already increased by about 2°C since pre-industrial times. Until the middle of the century a further increase of 1–2°C, depending on the region, is expected. Model results have shown that in the investigated Austrian forest soils about 10 per cent more CO_2 is produced by soil respiration when the air temperature increases by 1°C and about 20 per cent more CO_2 and N_2O is emitted if the temperature increases by 2°C. The increased temperature accelerates the decomposition of carbon and nitrogen stored in the soil.

The self-reinforcing process—the temperature increase caused by climate change leads to an increase in greenhouse gas emissions from soils and hence again reinforces climate change—was demonstrated during the project. After rewetting of dry soil (caused by extended summer droughts) N_2O production was especially enhanced. Simulation results showed that a temperature increase may intensify this effect.

Because of the effects of climate change and the associated limited natural water supply, farming will be increasingly difficult, and without adequate adaptation measures it could even become impossible in parts of eastern Austria. Landscape structures such as windbreak hedges can change the microclimate and improve the efficient use of water by crops by slowing down the wind speed, promoting dew formation and reducing evaporation. They also reduce wind erosion. The study of the economic limitations and opportunities of a landscape structure showed that very high yield increases are not necessary to obtain an economic advantage from a structured landscape. A structured landscape with 5 m high and 6 m wide landscape elements could have an average windbreak of ten times the size of the structure and could increase the yield by around 10 per cent (in relation to the crop harvest). Furthermore, if the anticipated positive external effects of landscape structures, such as promotion of biodiversity, impact on the natural scenery, recreational use and inter-enterprise preven-

tion of soil erosion, are taken into account, a macroeconomic benefit could also occur. Structuring an agriculturally used landscape is thus a useful climatic, economic and ecological measure in the face of the changing climate in Austria.

Another StartClim study assessed the impact of selected soil protection measures on soil erosion and rainwater retention in the landscape for a 1.44 km², agricultural watershed in the north-east of Austria. The period 1961–90 was used as a reference. No-till sowing and grassland decreased runoff by 38 and 75 per cent, respectively. The simulation results suggest that in future climate scenarios (2040–60) the effectiveness of the selected soil conservation measures will be similar or will reduce to 16 to 53 per cent.

The present mean net soil losses in the watershed were put at 2.57 for conventional soil management systems and 0.1 $t.ha^{-1}.a^{-1}$ for grassland. This corresponds to an average yearly loss of about 0.2 mm. Given an average yearly soil formation rate of 0.2 mm, the average soil loss remains tolerable. The current soil/land use does not exceed this limit. Most of the erosion occurs during spring. Under future climate scenarios conventional tillage will lead to changes in soil erosion of -55 to +22 per cent for moderate greenhouse gas emissions and -17 to +56 per cent for extreme greenhouse gas emissions. The use of no-till sowing reduces yearly soil loss rates to between 0.16 and 1.42 $t.ha^{-1}$. They are in the same range or slightly higher than under current conditions. The conversion to grassland minimises sediment yields leaving the watershed (> 0,03 $t.ha^{-1}.a^{-1}$). As the acceptable level is not exceeded, both soil protection measures can be recommended as sustainable soil/land management systems under future climatic conditions.

However, based on the available climate scenarios, climate-induced changes in the frequency and intensity of heavy rainstorms were only considered to a limited extent. As the general future trend indicates an increase in high-intensity rainstorms during the summer months, the results of this study may be too optimistic.

In previous studies changes have been reported in the composition and the abundance of insect pests in crop production in eastern Austria since 2000. A long-term-monitoring concept with permanent monitoring sites for the detection of climate-induced changes in pest abundance has been developed. The practical test of the monitoring concept in this study started with the estimation of cutworm numbers and cutworm damage on a grid of sampling points (0.25 m²) in a potato field. Based on these data, a sequential sampling system for a comparable estimation of cutworm density and damage was developed, which keeps the number of samples per field as small as possible. A maximum of 20 samples per investigation area for the estimation of cutworm density and 30 for the estimation of cutworm damage were used. This meant a maximum effort of 10 hours for cutworm density and 1.5 hours for cutworm damage.

Since cutworm incidence in 2008 was fairly low, nine farms in north-eastern Austria with severe cutworm damages in 2006 and 2007 were surveyed and data on site and cultivation characteristics and on experiences with regulation methods were collected. Additionally, the relationship between cutworm damage in 40 potato fields in 2007 and 2008, and climate, soil and landscape parameters were analysed. The positive correlation between cutworm damage and dry, warm weather conditions described in the literature was confirmed by the farmers' experience and by the regression analyses with cutworm damage and precipitation data. The cutworm damage was also positively correlated with the percentage of arable land in the area surrounding the sampling plot. Both factors should therefore be kept in mind when identifying future monitoring sites. Practical measures for the adaptation to increasing cutworm incidence might include crop rotation (e.g. no green cover crops after hot, dry summers, no susceptible crops in the following year) and irrigation of infested fields if feasible.

The focus of the next study was organic agriculture and tourism in the province of Tyrol (Austria). It analysed the options for an economic sector and the related societal subsectors to adapt to climate change and to help mitigate greenhouse gas emissions. General and regional specific knowledge was obtained from the literature and from 20 expert interviews (five in tourism and fifteen in the agriculture sector). Based on the protection motivation theory (*Schutzmotivationstheorie*) (assessment of threat and of ability to cope), the way in which individuals deal with climate change was analysed and developments in both agriculture and tourism were identified. An organic agriculture scenario provided information on the potential for mitigating greenhouse gas. Climate adaptation scenarios and the socioeconomic framework of possible developments were identified with focus on the year 2030. Scenarios for (organic) agriculture and tourism were embedded in this framework. A final analysis of the potential provided options for specific measures and intervention strategies.

Climate change adaptation can be of particular importance for tourism and recreation in high alpine areas. A simplified physical process model can be used to predict the kinds of damages to be expected in these areas as a result of the retreat of glaciers and the thawing of permafrost and hence for a discussion of adaptation measures. The importance of the predictive estimation of safety concerns and the early development of adaptive and mitigating measures emerged from a survey of over 300 tourists and recreationists to the high Alps. Based on a latent class analysis of stated choice, about half of the respondents were classified as ‘recreational hikers’ who also appreciate viewing the landscape. This group was relatively inexperienced and uncertain about the prevailing risks in the mountains. They would react strongly to changing conditions and would quickly abandon a hiking area if conditions became even a little unfavourable. In other words, this group could easily have a negative economic impact on a region.

As possible adaptation measures, all tourists and hikers see the continuous updating of maps as a primary mandate of the provincial and federal governments. In contrast, improving the trail markings is perceived as the responsibility of mountaineering clubs, which should also provide guides, training and trail maintenance. This latter aspect should also be partly the responsibility of communities. Investments for the protection and maintenance of the infrastructure and trails are perceived as being the responsibility of the provinces (32%), the communities (22%), the tourism industry (21%), and the federal government (18%). The poor appreciation of the dangers and the increasing risks highlight the importance of information.

An in-depth analysis of the mortality data in Vienna (1990–2007) revealed that starting from moderate temperatures there was a linear increase in daily mortality as the temperature increased. The average temperature of the previous 14 days was also negatively associated with the number of daily deaths: at lower temperatures the number of daily deaths increased. This association could be caused by general seasonal effects on mortality, i.e. that in general more people die in winter than in summer.

To target adaptation measures more accurately, an attempt was made to better define the population subgroups most in need. Heat-related mortality affects women, older people and people living in “poorer districts” to a greater extent. With the cold- and winter-related mortality no such differences between districts were evident. Interestingly, the relative risk of death on hot days was similar for patients in hospitals and other homes as for other persons. This finding could be the result of two overlapping effects: on the one hand patients in hospitals are usually more fragile and susceptible to additional stress factors; on the other hand trained hospital personnel help to reduce the risk.

There is no clear threshold level at which the mortality risk increases more steeply and therefore would be suitable as a trigger for measures, but it might be useful to invoke warning messages and other measures if minimum temperatures of 19°C or more are predicted.

1 The StartClim research programme

The StartClim climate research programme is a flexible instrument. Because of the short project duration it can react quickly to topical aspects of climate and climate change, analysed from different points of view and by different scientific disciplines. Although it is a low-budget research programme, around 100 Austrian scientists and almost 40 Austrian institutions have been involved in it since the outset. It has so far produced many interesting results that are often followed up in projects financed by other programmes and institutions. So far it has not only generated interesting results but has also helped to develop the know-how required within the Austrian climate research community.

StartClim was inaugurated in 2002 and is financed by a donor consortium presently consisting of nine institutions (see page 4). The Austrian Federal Forests joined the consortium in 2008. The donors are members of the coordinating group, which develops the research topics together with the scientific project leader. An international advisory board reviews project applications and final reports. The administrative tasks are carried out by the Austrian Federal Environment Agency. The scientific responsibility lies with the Institute of Meteorology, Department of Water-Atmosphere-Environment, BOKU – University of Natural Resources and Applied Life Sciences, Vienna.

An advantage of research financed by several donors is that it provides added value for all concerned, since every donor profits from the overall results, and synergies between projects and institutions can be made use of .

1.1 StartClim2008

The consequences of climate change are already being clearly felt. Some of the climate changes in progress this century can no longer be reversed. Adaptation measures are therefore no alternative to climate protection but have become an urgent and unavoidable necessity. Knowledge of the possibilities for adaptation is very sketchy and is far below what is possible and needed. StartClim 2008 is therefore devoted to the subject of adaptation to climate change.

The projects in StartClim2008 deal with adaptation of forest soils to a changing climate and methods to decrease evapotranspiration, erosion and insect pests in agriculture, adaptation to climate change in organic farming in the mountains and permafrost degradation, and the impact of adaptation measures to the mortality risk in Vienna.

1.2 Structure of this report

The StartClim2008 report consists of an overview of the results in both German and English along with (separately bound) documentation in German in which the individual projects are described in detail by the respective project teams. All reports are published as a CD as well. A short summary will be published as a brochure. All reports and documents about StartClim2008 will be made available for download at http://www.austroclim.at/startclim/, the StartClim website.

1.3 Organisational aspects of StartClim2008

The organisational structure of StartClim2008 was similar to that of earlier StartClim phases. It consisted of seven subprojects involving 34 people from 11 institutions and representing over 40 months of scientific work calculated in the project proposals. Of the 34 contributing scientists, 13 are women.

In order to promote scientific exchange between the individual subprojects, two workshops were held with members of the scientific board participating. All scientists were invited to present the results of their ongoing work and to discuss links between the subprojects.

The information and data exchange within the StartClim community was again supported by the FTP server and the StartClim website (http://www.austroclim.at/startclim/) at the Institute for Meteorology of the BOKU University of Natural Resources and Applied Life Sciences, Vienna.

2 StartClim2008 projects in detail

2.1 StartClim2008.G: Adaptation of forest soils to a changing climate

Carbon dioxide (CO_2) is the most relevant greenhouse gas (GHG), but methane (CH_4) and nitrous oxide (N_2O) are also not negligible. Although emissions of CH_4 and N_2O are small in comparison to CO_2, they contribute considerably to the greenhouse effect as they have a 23-fold (CH_4) and 296-fold (N_2O) higher global warming potential than CO_2 (IPCC, 2004). Nitrous oxide influences the radiation budget of the earth indirectly by acting as a catalyst for ozone (O_3) production in the troposphere (Crutzen, 1997; IPCC, 2004). Soils are considered to be the major source of N_2O (55–65%) and CH_4 (15–45%, in wetlands), but they are also the only known sinks for methane (in aerobic soils; Macdonald et al., 1996). Because of the complexity of the processes involved (mineralisation, nitrification, denitrification, methane oxidation and reduction) it is still difficult to estimate the regional and global source/sink potential of soils for N_2O, CH_4 and CO_2.

Few data are available about the effect of increased air temperature or changed precipitation patterns on carbon and nitrogen mineralisation in soils. As microbial activity is very sensitive to temperature and moisture, soils may become sources of nitrogen and carbon trace gases. Increased nitrogen deposition or land-use changes may lead to a change in soil processes and microbial activity and thus to a change in the source and sink potential of soils. Because of the high spatial and temporal variability of microbial processes (“hot spots” and “hot moments”), field or laboratory research may not be sufficient to estimate these changes. That is why we are dependent on simulation models. By testing and improving process-oriented models, the uncertainties regarding the estimation of GHG emissions from soils can be reduced. Emission hot spots can be detected more easily and directed strategies for emission reduction can be developed (IPCC, etc.).

The aim of this study was (1) the consolidation and processing of all available and relevant data for model initialisation, calibration and validation (2) the application and testing of a biogeochemical model (framework: MOBILE-DNDC, module: Forest-DNDC2) for simulation of carbon and nitrogen cycles and gas fluxes for three selected forest sites in Austria (3) identification of model weaknesses and possible model improvements (4) scenario analysis and sensitivity studies.

Existing data from several research projects were collected (more than ten years of data from three different forest sites), structured, consolidated and entered into the model, which was adapted to their particular characteristics. Several improvements were carried out including the development of a new temperature response function and the testing of alternative moisture functions. Good model results were obtained for $CO_2$and N_2O emissions for all three sites. A successful validation of the model with the data for the heated soil plots was achieved. Model calculations showed that a temperature increase of 1°C would produce up to 10 per cent more CO_2emission. With a temperature increase of 2°C, 20 per cent more $CO_2$and N_2O would be emitted. This is due to the increased microbial decomposition of stored carbon and nitrogen in soils. By comparison: Austrian transport produces 2.7 t $ha^{-1}.a^{-1}$ of CO_2equivalent. The forest soil in Tyrol emits 6.6 t $ha^{-1}.a^{-1}$, most of which is taken up by forest plants.

The self-reinforcing process—the temperature increase caused by climate change leads to an increase in greenhouse gas emissions from soils and hence reinforces climate change—was confirmed by the presented results. After rewetting of dry soil (caused by extended summer droughts) N_2O production was especially enhanced. Simulation results showed that a temperature increase may intensify this effect.

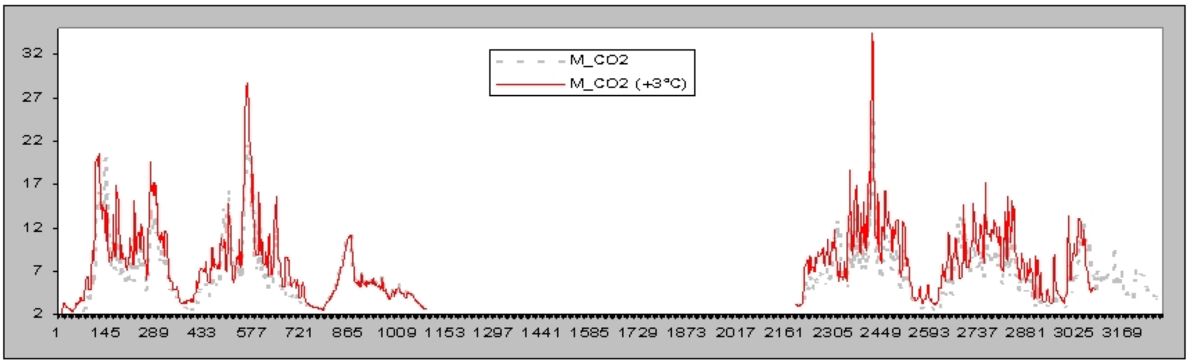


Fig. 1 : Modelled CO2 emissions in Schottenwald at current temperatures (grey) and predicted CO2 emissions for a temperature increase of 3°C.

2.2 StatClim2008.E: Development and economic valuation of landscape structures to decrease evapotranspiration on agricultural acres with account taken of climate change and biomass production

Regionalised climate scenarios for the eastern part of Austria (DUBROVSKY, 2005) show an explicit increase in temperature and approximately constant rainfall. An increase in the average annual temperature for the 2020s of about 1.9°C and for the 2040s of about 2.5°C compared to the climate period 1961–90 due to the changing temperature conditions, an increase in potential evaporation of approximately 18 per cent and 25 per cent for the 2020s and the 2040s, respectively, can be expected (EITZINGER et al., 2005). Water is already one of the limiting factors in agricultural production in the eastern part of Austria. Adaptive measures to ensure the efficient use of this resource, which is already limited and is likely to become scarce in the future, will play an important role in the conservation of agricultural production.

Because of the anticipated changes in climatic conditions, agriculture could become increasingly difficult and, without appropriate adaptation measures, even impossible in some parts of eastern Austria. One possible adaptation measure would be to influence the microclimate. This can be done by establishing landscape structures (e.g. wind hedges) that would break up landscape and significantly improve the water use efficiency of the agricultural fields.

With account taken of the various climate change scenarios, the climatic, economical and ecological utility of landscape structuring was investigated and an initial basis for further in-depth research and decisions developed.

A variety of landscape structures were discussed for multifunctional land use: in addition to the positive influence of the microclimate, consideration was also given to the protection of the soil from erosion and the sustainable maintenance of soil fertility, and additional economic uses of landscape structures, such as the production of biomass and the harvesting of wild fruits. Because of the current lack of data, the research project was mainly based on literature and data from other projects together with the economically-based scenario analysis.

Three possible landscape structure alternatives were considered: ligneous perennial plants with particular regard for functional biodiversity, ligneous perennial biomass crops in short rotation, and herbaceous—annual to perennial—plants.

These landscape structures have a positive effect on the microclimate and affect the water supply by reducing wind speed, wind erosion and evaporation and by promoting dew formation. Under today’s climatic conditions, this will lead to an increase in the crop yield. With the anticipated climatic changes, it is expected that farmers will be able to maintain their income in spite of the unfavourable climate conditions.

Based on the literature analysis, a wind-protecting effect can be assumed in an area 10 to 20 times the width of the landscape structures (see, e.g. MAZEK-FIALLA, 1967). A 5 m landscape structure causes a potential windbreak up to 50 to 100 m and thus has a positive influence on the water supply for this arable land. Literature research also shows that the landscape structures should have a minimum width of 6 m for a significant climate impact and thus a positive influence on the water and soil erosion to take place (DVL, 2006; MEYERHOFF, 2006).

The effect of climate protection on the various planting variants also needs to be examined. While herbaceous biomass crops are harvested annually, there is a reduction in the overall wind protection. Ligneous perennials plants are harvested in multi-year intervals, depending on their use. Ligneous perennial plants with a specific biodiversity function (hedges) have the highest measured wind-protection effect. A possible increase in the yield of cultivated crops as a result of the landscape structure depends on the (wind permeability, harvest time and harvest frequency), height and width. Other factors such as abiotic site conditions (soil and rock subsoil, water, nutrient and heat budget, sunlight, etc.) and the crop itself also influence the yield.

The economic analysis was based on a local field crop rotation in conventional farming in the eastern part of Austria, and the related crop yield and price forecasts. The economic limitations and opportunities of landscape structuring in terms of direct economic impact and effects were estimated.

A landscape structure 5 m high and 6 m wide could create an average windbreak of ten times the size of the structure and may increase the yield by 10 per cent (in relation to the crop harvest), which creates an economic advantage for the farmer. If the average wind protection is 20 times the height of the landscape structure, farmers can benefit by an increase of approximately 5 per cent in the natural yield.

Thus high crop-yield increases are not needed for structured landscapes to provide an economic benefit. The selected landscape components themselves can be advantageous in both food and non-food production.

If the expected positive external effects of greenhouse gas reduction, soil and landscape structure with increased biodiversity are taken into account, the overall potential economic benefits rise even further. The 5 to 25 per cent increase in natural yield (for the imputed crops) required for the landscape structures to produce a positive result could thus be significantly reduced in the face the growing importance of external effects in the future.

If the current management (tillage, crop rotation, variety selection, etc.) continues, we concluded that in the light of climate change, agricultural land may need to be structured or portioned to prevent an increase in evapotranspiration and to maintain the yield and soil fertility in the long term.

Even today, the structuring of agricultural land is important as a means of increasing yield stability and preserving soil fertility for future generations. The results described here are based on a scenario with average values. For a further detailed ecological and economic evaluation for specific landscape structures more scientific investigations are needed:

- Modelling the close-up microclimate of different landscape structures (ligneous perennial plants with particular regard to biodiversity function, ligneous perennial biomass crops in short rotation and herbaceous—annual to perennial—biomass plants)
- Determination of the effects of landscape structures on the crop yield and the amount of plant-available water in adjacent fields
- Surveying the yield of the landscape structure (biomass plants, etc.) itself
- Extended economic modelling on the basis of the field data with account taken of external effects

- Studies on the economic optimisation of landscape structures
- Identification of relevant parameters for structuring individual landscapes in relation to specific regional factors and to the individual farm situations
- Identification of acceptance of landscape structuring

2.3 StartClim2008.B: Which adaptations of soil erosion protection measures can be recommended for expected climate change impacts?

"Only fertile soil produces healthy crops and clean groundwater." In the long term, soil erosion by water reduces not only soil productivity but also the storage and filtering function of soils. The main objective of sustainable soil and land use must be the conservation and improvement of the fertility and quality of our soils. Decreasing soil loss through soil conservation measures represents a major contribution to achieving this goal.

Within this project two soil conservation practices were selected and compared with a conventional soil tillage/management system:

1) Conventional tillage (CT)
2) Direct seeding with cover crop during winter (NT)
3) Grassland (GRASS).

The goal of this study was to assess the effect of the selected soil protection measures on soil erosion and rainwater retention in a 1.44 km² agricultural watershed in the north-east of Austria. Based on the reference period of 1961–90 the effect of these soil conservation methods were simulated for a climate scenario 2040–60 for IPCC A1B (moderate greenhouse gas emission) and A2 (extreme greenhouse gas emission) scenarios. For both scenarios a low and high temperature increase was assumed and a time series of 100 years was generated.

Surface runoff, soil loss and sediment yield were simulated with the GIS-based version of the WEPP erosion model. The model was calibrated and validated using long-term measurements from field plots in the watershed.

The results of this study show that under the assumed future climate scenarios a reduction in annual precipitation of 7 to 18 per cent can be expected. With moderate greenhouse gas emissions, surface runoff from conventional tilled fields (CT) will be reduced by 42.5 to 60 per cent. Despite significantly lower annual precipitation under IPCC scenario A2, a smaller decrease in surface runoff of between 7.5 and 20 per cent is simulated because of an increase in heavy-intensity rainstorm events.

Under current climatic conditions no-till sowing and grassland decrease runoff by 38 and 75 per cent, respectively. The simulation suggests that under future climate scenarios (2040–60) the effectiveness of the selected soil conservation measures will be similar (A1B) or slightly reduced to between 16 and 53 per cent (A2). This means that under future conditions with lower precipitation surface runoff will decrease slightly. Overall, water retention in the landscape will diminish and less water will be available for plant production.

For the current situation, average net soil losses in the watershed range from 0.01 $t.ha^{-1}.a^{-1}$ for grassland to 2.57 $t.ha^{-1}.a^{-1}$ for conventional soil management systems. Under this system the tolerable soil loss of 2.5 $t.ha^{-1}.a^{-1}$ is reached, which corresponds to an average yearly soil formation rate of 0.2 mm. Most of the erosion occurs over a short period in spring between seedbed preparation and beginning of vegetative crop development when storm events with highest rainfall intensities occur.

Under future climate scenarios, conventional tillage will lead to changes in soil erosion by -55 to +22 per cent (A1B) and -17 to +56 per cent (A2), respectively. Under extreme climatic conditions (A2) average soil loss will reach 4 $t.ha^{-1}.a^{-1}$ and will therefore exceed the soil loss tolerance limit.

Tab. 1: Compilation of runoff and soil erosion results for investigated soil conservation methods

		1961-1990	2040-2060	
			moderate emission scenario (A1B)	extreme emission scenario (A2)
Precipitation ($mm.a^{-1}$)		535	500 - 506	440 - 471
Temperature (°C)		09.Mai	10.5 - 12.1	10.8 - 12.6
Surface runoff ($mm.a^{-1}$)	CT	4	1,6 - 2,3	3,2 - 3,7
	NT	2,5	1,0 - 1,5	2,5 - 3,1
	Grass	0,9	0,4 - 0,6	1,5 - 2,1
Soil erosion ($t.ha^{-1}.a^{-1}$)	CT	2,57	1,16 - 3,14	2,14 - 4,00
	NT	0,35	0,16 - 0,22	0,26 - 1,42
	Grass	0,01	0,01	0,03
Sediment yield ($t.ha^{-1}.a^{-1}$)	CT	1,51	0,63 - 1,46	1,29 - 2,38
	NT	0,22	0,10 - 0,15	0,20 - 0,52
	Grass	0,01	0,01	0,03 - 0,04

No-till sowing reduces the yearly soil loss rates to values between 0.16 and 1.42 $t.ha^{-1}$, which are in the same range or slightly higher than under present conditions. The conversion to grassland minimises soil losses (>0.03 $t.ha^{-1}.a^{-1}$). Average soil erosion rates always indicate that within the watershed much higher soil losses can appear depending on field size and slope length and steepness. Nevertheless, once in nine years significantly higher erosion exceeding the tolerable soil loss must be expected.

The methodology used is suitable for controlling the effectiveness of soil conservation measures in changing climate conditions. Possible restrictions include changes in crop rotations and crop productivity as a result of new varieties and breeds not considered in the simulations. Rainfall intensity is one of the main drivers of soil erosion and affects the process more than the amount of rainfall. Climate-induced changes in the frequency and intensity of heavy rainstorms were simulated on the basis of the available information but may differ from expected future trends.

Both investigated soil protection measures can be considered as sustainable land use systems under future climatic conditions as they do not exceed the tolerable soil loss on a long-term, basis. Nevertheless, on steep slopes the conversion from CT to NT alone will not be sufficient.

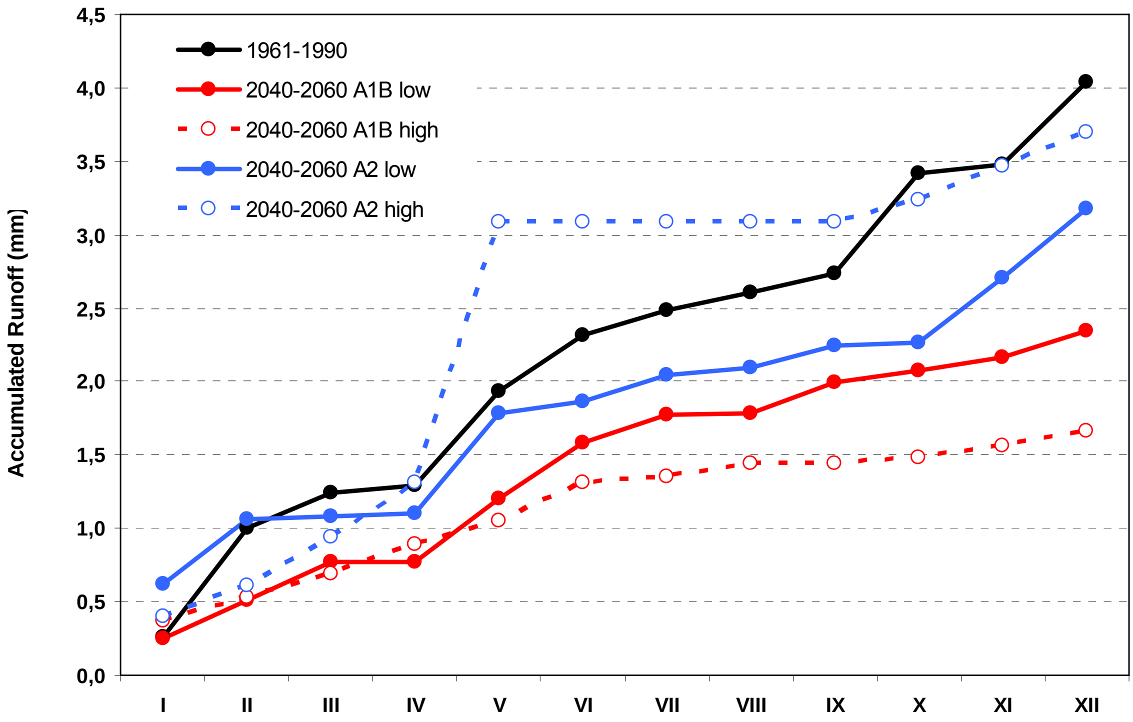


Fig. 2 : Temporal distribution of surface runoff in the watershed under conventional tillage (CT) for present conditions (1961–90) and for future climate scenarios (2040–60) with moderate (A1B) and extreme greenhouse gas emissions (A2)

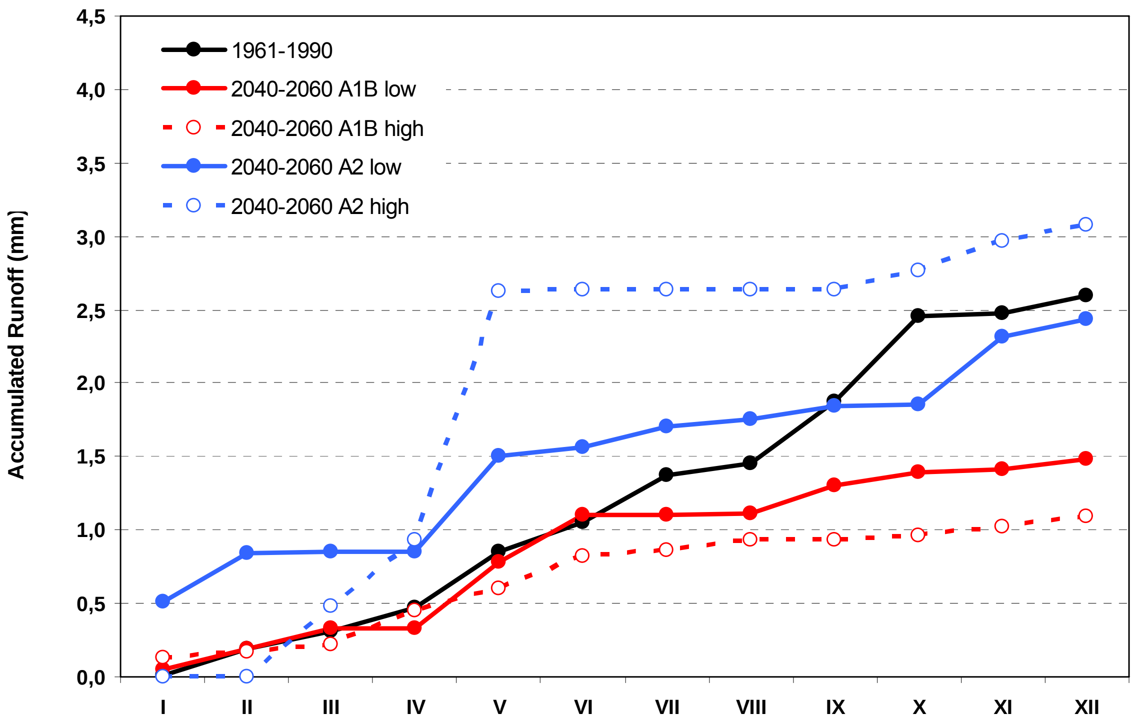


Fig. 3 : Temporal distribution of surface runoff in the watershed under direct seeding (NT) for present conditions (1961–90) and for future climate scenarios (2040–60) with moderate (A1B) and extreme greenhouse gas emissions (A2)

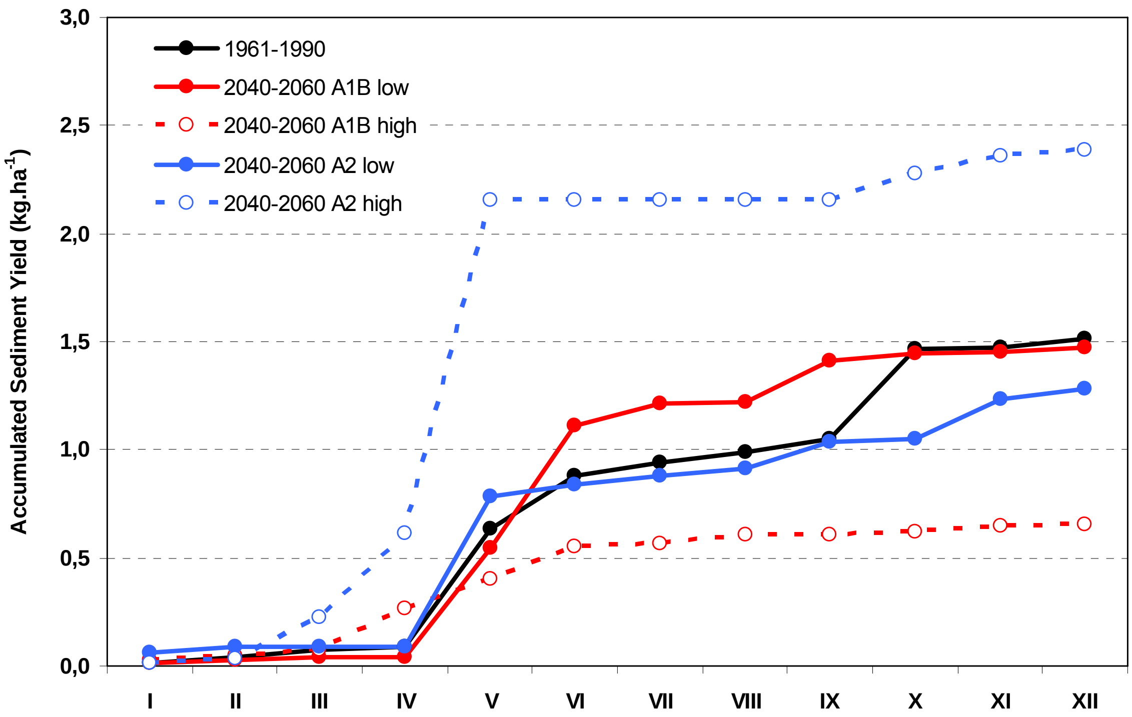


Fig. 4 : Temporal distribution of sediment yield from the watershed under conventional tillage (CT) for present conditions (1961–90) and for future climate scenarios (2040–60) with moderate (A1B) and extreme greenhouse gas emissions (A2)

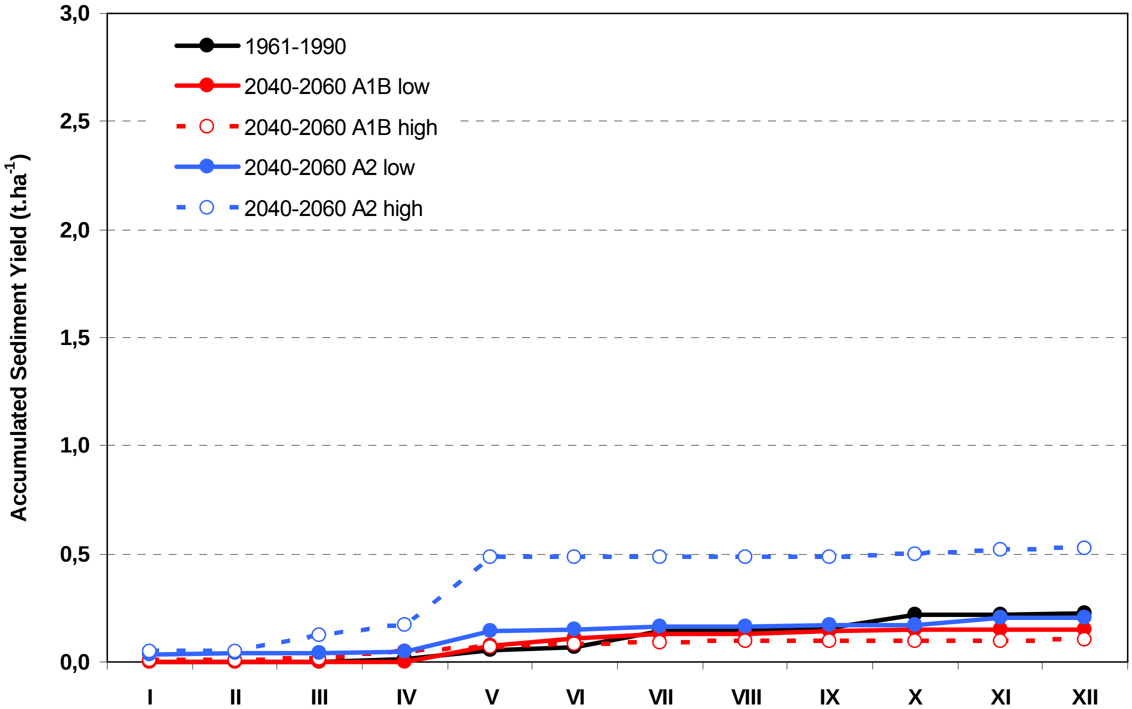


Fig. 5 : Temporal distribution of sediment yield from the watershed under direct seeding (NT) for present conditions (1961–90) and for future climate scenarios (2040–60) with moderate (A1B) and extreme greenhouse gas emissions (A2)

For these areas the following adaptations of the current erosion control practices are proposed:

- For slopes of over 10 per cent, erosive crops like corn, potatoes and sugar beet should be replaced in the crop rotation by crops that cover the soil most of the year.
- To convey the surface runoff in a non-erodible way, grassed waterways with a width of around 5 m should be laid out in the thalweg.

Soil is a limited resource and will represent the main basis for food production for the next generations. The protection of our soil therefore needs to be accorded the highest priority. Reduced soil tillage/management systems and grassland are effective and sustainable soil use systems even under future climate conditions because they maintain and improve the different functions of the soil.

2.4 StartClim2008.C: Practical testing of the monitoring concept "Adaptations of insect pests to climate change in crop production of Eastern Austria" (StartClim2007.C) by investigating the distribution of current cutworm (*Agrotis segetum*, *Schiff.; Fam. Noctuidae*) damage as a function of site-related and climatic factors

Recent changes in the composition and abundance of insect pests in organic crop production in eastern Austria were reported in the previous study StartClim2005.C3-a. There were remarkable outbreaks of thermophilic pest insects especially in warm and dry years like 2003. A causal connection between these changes and climate change could only be assumed, because of the lack of comparable long-term data on insect pest occurrences. Consequently, an insect-pest monitoring system with permanent monitoring sites was recommended. This system should provide data on pest population densities and damage capable of yearly and regional comparison. In future, these data could help to detect climate-induced changes in pest abundance so that adaptation measures can be taken in good time. In StartClim2007.C, a long-term-monitoring concept for insect pests was developed to cover the most relevant crops, pests and climatic regions in the crop production area of eastern Austria. The participation of existing monitoring and warning systems is part of the concept.

In spring and summer 2007, severe cutworm damage was recorded from maize, potatoes and cover crops in north-eastern Austria (Weinviertel). Cutworms are the soil-dwelling larvae of noctuid moths ("cutworms", fam. Noctuidae; major species: turnip moth *Agrotis segetum*). Since the positive effects of hot and dry weather on the development of these species have been extensively described in the literature, the reported damage provided an opportunity to test the theoretical monitoring system in practice.

The aim of this study was to develop practicable methods for the estimation of cutworm density and damage so that conclusions could be drawn on the required density and distribution of monitoring sites, and to devise suitable suggestions for practicable adaptation to higher cutworm densities as a consequence of global warming.

Methods

First, a practicable procedure for sampling cutworm density and damage was developed. Then both parameters were estimated on a grid of 81 sample points (0.25 m²) on a potato field, in order to characterise the cutworm distribution (uniform, random, aggregated). Based on these data, a sequential sampling system for a comparable estimation of cutworm density was developed, which keeps the number of samples per field as small as possible. Since cutworm infestation in the test year 2008 was quite low, nine farms in north-eastern Austria with severe cutworm damage in 2006 and 2007 were surveyed and data on site and cultivation characteristics such as crop rotation and tillage were collected. Comments by the farmers on factors influencing cutworm occurrence and experiences with regulation and adaptation methods were also documented.

Additionally, regression analyses with cutworm damage data for 40 potato fields in 2007 and 2008 from an ongoing project on organic wireworm regulation and climate, soil and landscape parameters were conducted. Based on the regression results, the farm surveys and literature, conclusions on factors favourable to cutworm damage and criteria for dispersion and density of monitoring sites were drawn.

Results and conclusions

The combination of the sequential sampling system and the sampling procedure for estimating cutworm density and damage is practicable, allows quick acquisition of comparative data and can be adapted to the requirements of the main and auxiliary monitoring sites. A maximum of 20 samples per investigation area is required for the estimation of cutworm density and 30 samples for the estimation of cutworm damage. This means a maximum of 10 hours of effort for cutworm density and 1.5 hours for cutworm damage. On basis of this sequential sampling system, estimation procedures for other insect pests can be developed.

According to the farmers, severe cutworm damage is often associated with dry, hot weather. In the relevant literature, temperature and soil moisture are described as key factors in cutworm development. In seven out of nine surveyed farms with recent cutworm damage, the soil was quite dry. The regression analyses showed a negative relation between cutworm damage and mean annual precipitation (1961–90). Negative correlations between the cutworm damage in 2007 and 2008 and the total precipitation from September to October of the preceding years suggest that the weather conditions in this season regulate the *A. segetum* population density.

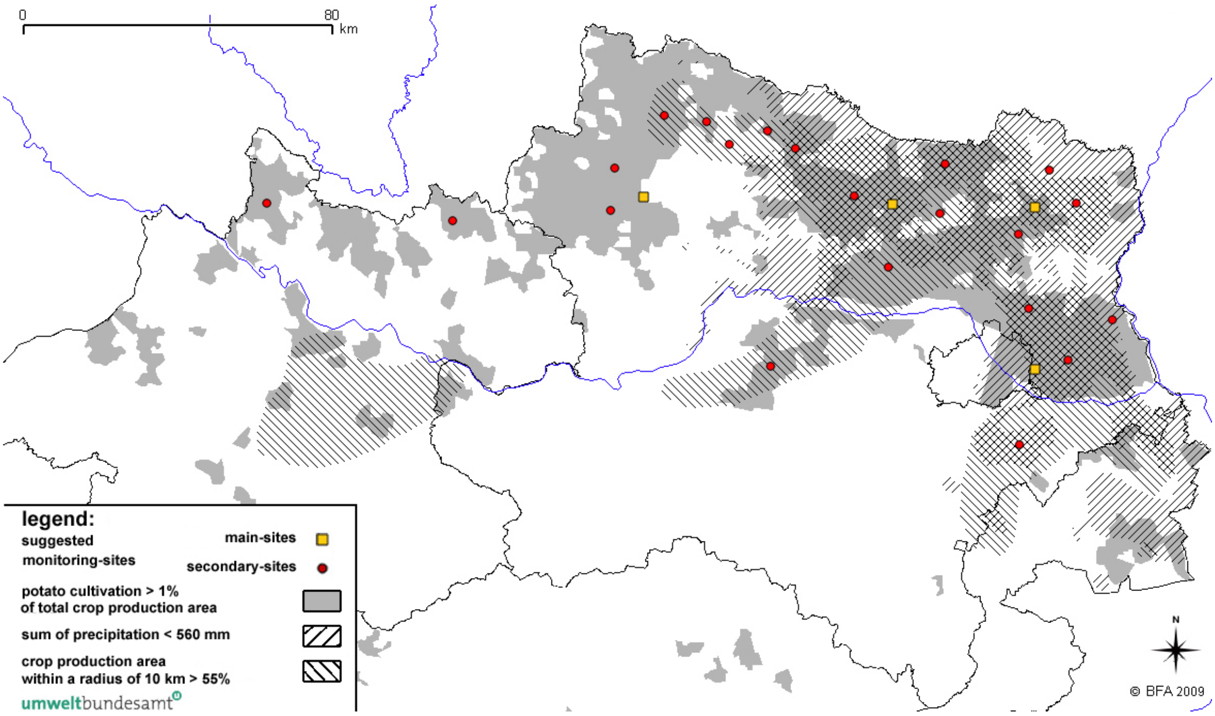


Fig. 6 : Suggested network of monitoring sites for the estimation of cutworm densities and damage as a function of annual precipitation and percentage of farmland in the area surrounding a site. According to the results of a logistic regression analysis (r2~24%), the probability for medium to severe cutworm damage (≥ 10% of the potato plants are damaged) is more than 70 per cent if the total mean annual precipitation is < 560 mm (1961–90, HARLFINGER & KNEES 1999) or if the proportion of crop production area within a radius of 10 km is > 55 per cent (CORINE LAND COVER 1990), respectively. The map with potato production regions is based on data from STATISTIK AUSTRIA (2009).

Cutworm damage was also positively correlated with the percentage of arable land in the area surrounding the sample plots. It is probable that in an open landscape dominated by farmland, adult *A. segetum* females can migrate to the susceptible crops more easily than in heterogeneous landscapes dominated by woodlots. Thus, not only the precipitation characteristics but also the proportion of surrounding farmland (radius = approx. 10 km) should be kept in mind when locating future monitoring sites. The figure shows a suggested network of monitoring sites for the estimation of cutworm densities and damage with account taken of both factors.

The farmers' experience suggests that there is a strong correlation between sowing time and cutworm damage. Cutworms feeding on the young seedlings can result in a total loss in crops like maize. Green cover crops in autumn were quite often affected by severe cutworm damage: presumably they provide a substrate for egg deposition and food for second-generation larvae. Following dry and warm autumn months, overwintering cutworms can even cause damage in the following crops.

Changes in crop rotation (e.g. no green cover crops, no susceptible crops in the following year) after hot, dry summers could help to prevent cutworm damage. Since cutworms are quite sensitive to high soil moisture, the irrigation of infested fields could be an additional regulation measure, if feasible.

2.5 StatClim2008.D: Organic agriculture in the mountains of Tyrol—contributions to mitigating climate change and adaptation strategies

Our research focused on the effect of climate change on Tyrolean (organic) agriculture and tourism. We conducted an analysis of an economic sector and related subsectors to determine how they could help mitigate climate change and adapt their systems. The findings were based on a literature review and 20 expert interviews.

The investigation involved four phases:

- AS 1: Perception of climate change
- AS 2: System analysis—description of status quo
- AS 3: Scenario analysis—description of possible futures
- AS 4: Analysis of potential—description of possible strategies and measures

Perception of climate change

Almost all interviewees express their concern that the likely developments are increasingly undesirable. They also inferred that the gap is widening between structural change including GMO and traditional regional resource-oriented organic agriculture without GMO. There is a conflict in the strategies for adaptation to climate change. On the one hand technical solutions (e.g. snow makers) allowing for current lifestyles are preferred. On the other hand only ecological approaches (e.g. organic agriculture) are regarded as being appropriate for achieving the desired aims.

The way individuals deal with climate change was analysed using the protection motivation theory (*Schutzmotivationstheorie*) (assessment of threat and of coping). The most important analytical categories are "perception, threat, coping, adaptation and mitigation" (see table D-1). In most of the interviews, we noted a difference between probable and desirable development:

- Desire: regional, resource-conserving organic agriculture without GMO, in keeping with agricultural traditions and innovative tourism
- Probability: the continuation of structural change (with GMO)

In the interviews scientists and practitioners gave typically distinct answers to the question of the relevance of climate change to their organisations.

- Scientists started with the effects of climate change and concluded with general adaptation options. "What happens if climate change comes"? Recommended measures: development of regional climate models to quantify uncertainty; assessment of natural risks; simulation models for regional scenarios on extreme climate events and narrative scenarios on social development as a communication strategy for public debate.

- Practitioners started with specific adaptation measures, while general effects (will be warming) were subordinate. "What will we do if climate change happens"? Recommended measures: organic wine production, organic strawberries, salad or squash production.

There is a vague awareness of climate change but no clear idea about it, and the general attitude is of general concern rather than the sense of a specific real threat. There is also a feeling of powerlessness because of the complexity of the topic, combined with a "dismissive indifference".

In summary it would appear that in spite of specific and far-reaching insights into the context and possibilities for action, the climate debate and ideas about specific actions are only slowly penetrating into public awareness.

System analysis—description of the current situation

A quarter of the agricultural land in the province of Tyrol is farmed organically. The contribution of subsidies to agricultural income in mountain farms is on average 70 to 80 per cent, in some cases 100 per cent. The maintenance of a typical cultural landscape is of high importance. Two strategies situated between the optimisation following a market approach and a subsidy approach can be identified: (a) production-oriented (farming) and (b) multifunctional orientation (agriculture).

Tab. 2: Summary of results based on expert interviews

	(Bio-)agro sector	*Tourism sector*
Perception	People confirm climate change; the perception is based on the media and is often diffuse in the specific living context; precise description of causes and effects, but confused perception on future effects	No clear differences regarding perception of climate change between (organic) farming and tourism sectors
Threat	Composure; there is no threat to existence; concern could come in future, but nothing specific, rather the possibility of a threat for future generations	No snow is the biggest disaster—a feeling of powerlessness/ helplessness, the acceptance of this fact making it easier to deal with(rationalisation)
Coping	Concern that climate change is coming closer but belief that the effects can be coped with and can therefore be ignored: "dismissive indifference"; assurances satisfy the general need for security	There are no alternatives: no option without snow; fatalistic resignation as a result; summer tourism and other exploitation will not cover losses; fear that "heat fugitives" (Mediterranean as "raw material") could go elsewhere
Adaptation / measures	Resorting to traditional measures, also from other regions (e.g. organic wine production, south Tyrol), but uncertainty about these production methods; organic farming: robust system that will stand up to climate change, but no clear idea about the its possible contribution	Technical adaptation mentioned mostly but structural challenges (e.g. train connection); "low" oil price is hindering CO_2-reduced travel and driving behaviour
Mitigation / measures	Organic farming and region: transport argument, organic farming is believed in general to be climate-friendly	Climate-neutral travel but possible added value but not a relevant factor; technical measures: e.g. photovoltaic and geothermal power for tourist infrastructure

A variety of labels exist in the organic sector based on a wide-ranging set of guidelines. Distinctions can also be made between trademarks on the basis of regionalisation, mountain agriculture and purchasing strategies. Both developments—labels and trademarks—make it difficult for consumers to find their way. Organic products from mountain regions are the central focus of marketing strategies.

Tourism is of high relevance in the Tyrolean economy. There are two strategies: (a) authenticity ("intact nature and cultural landscape") and (b) production ("events and actions").

Future developments within these four corner positions call for a discerning approach to the mitigation of greenhouse gases and strategies for adaptation to climate change.

Scenario analysis—description of possible futures

The scenario design consists of two parts:

(1) The scenario on climate mitigation related to (organic) farming includes the complete conversion of Tyrolean agriculture to organic farming based on three system components (mineral nitrogen fertiliser, forage, cattle stocking rate). The potential for mitigation in this already extensive grassland area is 0.5 per cent of total Austrian agricultural emissions. But these are only rough estimates. Several components (e.g. nutrient surplus, nitrate leaching into groundwater, primary energy use) are not included because of the absence of relevant data. Further integration of agronomic and nutritional factors will increase the potential for reducing greenhouse gas emissions as a result of organic products.

The assessment of the organic farming system should not be confined to a single indicator (greenhouse gas emissions). The effects are broader (e.g. environmental protection, biodiversity, social services).

(2) The climate adaptation scenario includes the worst case climatic development and the socioeconomic framework until the year 2030. Embedded in them are two scenarios relating to climate change in agriculture and tourism:

Core field scenario I (intensification) in climate context

- AGRI: "Farming" (organic farming as a niche)
- TOUR: "Production" (events and actions)

Core field scenario II (extensification) in climate context

- AGRI: "Agriculture" (organic farming as a model)
- TOUR: "Authenticity" (healthy nature and culture landscape)

Tab. 3: Greenhouse gas reducing potential with total conversion to organic farming in Austria and Tyrol

	Austria		*Austria (organic)*	*Tyrol*		*Tyrol (organic)*
components	*total*	*organic*	*GGE reduction t $CO_2e\ a^{-1}$*	*total*	*organic*	*GGE reduction t $CO_2e\ a^{-1}$*
(a) t N-mineral fertiliser (2007)	103,700 (1)		776,713	100		749
(b) total number of cattle (2007)	2,000,196 (2)	340,033 (2)	186,635 (3)	182,559 (4)	37,791 (4)	16,057
(c) stocking rate LSU/ha in grassland farms (2007) (5)	1.21	1.07	248,029			23,006
GGE total emissions (2007)	7,900,000		1,211,377			39,812

Sources: (1) Grüner Bericht 2008; AMA 2007, (2) Grüner Bericht 2008, Tab. 3.1.25, (3) UBA 2009b: 224ff, 241 (4) Grüner Bericht 2008, Tab. 3.1.15b, (5) Grüner Bericht 2008: 234; LSU -life stock unit

Analysis of potential—description of possible strategies / measures

Based on the scenarios we analysed the development potential in the agriculture and tourism sectors. We identified alternatives for production, trade and marketing, bio-energy, nature conservation and landscape management subsectors in the agriculture sector, and winter and summer tourism subsectors in the tourism sector. Intervention strategies include education / consultation / public relations, research and development, subsidy programmes and marketing.

2.6 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)

In the cryosphere of the European Alps, glacial ice and permafrost respond sensitively to climate change. In this context, glacier retreat, increasing subsurface temperature, slope instability, and mass movements are clear indications of climate and landscape change in alpine environments. Moreover, these processes considerably affect the current and future potential for natural hazards.

This study was designed to analyse, estimate and simulate the present and future occurrence of glaciers and permafrost as a function of geomorphologic changes. It also focused on their impact on geomorphologic hazards and risks for tourism in the upper Tux valley. The instruments used in the study were field surveys, remote sensing, GIS-based analysis and interviews with tourists.

The Tux valley is framed by the glaciated main ridge of the Zillertaler Alps. Tourism, including accommodation and related services, are of essential economic significance. Besides winter sport activities, which can be pursued year-round in the glacial region, the area offers plenty of opportunities for further alpine sport activities. Tux is the base for numerous hikes and tours into the high alpine regions. A number of alpine huts operate throughout the year.

Currently the Tux valley comprises a permafrost area of about 15 km², which corresponds to 13 per cent of the study area (116.4 km²). The major part of the permafrost area is located at an altitude between 2,500 and 3,100 m. Beneath 2,400 m frozen ground is sporadic. If mean annual air temperature (MAAT) decreased by 1.5°C from the present-day average, corresponding to climatic conditions 100 to 150 years ago, the permafrost area would extend to about 24 km² at an altitude of 2,200 to 2,900 m. This means that before warming started around 150 years ago, there was a larger area of geomorphologically stable permafrost . The anticipated increase in MAAT of 1.5°C will reduce the permafrost area by approx. 27 per cent to about 12 km². The greatest degradation will occur between 2,400 and 2,900 m. Once this scenario is realised, permafrost would be exclusively present at altitudes of 2,700 to 2,900 m in the Tux valley.

In 1850 glaciers covered an area of 20.6 km² along the main ridge of the Zillertaler Alps. At present, the glaciated area has been reduced to approx. 7 km², a decrease of 65 per cent, which is above the mean shrinkage compared with other regions of the eastern Alps. The largest glacier in terms of area and volume is the Gefrorene-Wand-Kees, which at present comprises an area of 4.3 km², and is thus of substantial economic importance for the Hintertux area. So far, shrinkage of the glaciated area has been relatively moderate at 42 per cent. However, the scenario of an increase of 1.5°C in mean summer temperature by the middle of the twenty-first century causes the equilibrium line altitude to rise 270m. As a consequence, only three glaciers of a limited area would remain. Because of its flat topology, for example, the Gefrorene-Wand-Kees would almost completely disappear.

Numerous debris flows can be identified in the study area. They are spread mainly in areas where the permafrost has degraded during the last 150 years. Moreover, debris flows are present in areas of glacier retreat. The ongoing process of permafrost degradation could cause the development of additional debris flows and increase bed-load deposits. The scenario of an increase of MAAT of 1.5°C will extend the areas at risk to 1.78 km² in the critical slope inclination of 25–45° and as a function of the petrological conditions. Buildings, roads and cable cars are not situated in the areas primarily at risk but depending on the topography they might be tangentially affected.

A rise in MAAT would also increase permafrost degradation in bedrock resulting in a rise in rock fall activity. In this context, an increase of 1.5°C would increase the area affected by permafrost degradation to 6.84 km², for the most part in stable geological units. Hazardous areas where the critical slope exceeds 40° would make up 1.78 km² in total. The potential rock fall areas take in infrastructural elements, in particular hiking trails.

Mass movement relating to glacier retreat and permafrost degradation affect and limit high alpine tourism and recreation. Because of the extensive retreat of glacier tongues and the complete meltdown of glacier surfaces, traditional mountain routes now cross morainic debris and inaccessible mountain flanks. This makes them more difficult, time-consuming and dangerous for the average hiker. Many trails are affected by erosion, rock fall, meltdown of the glacier tongues making the terrain steeper, a reduction in glacier thickness causing the emergence of cliffs and enlarged bergschrunds, and significant changes in the runs of glacial streams. In order to reduce or avoid associated risks, many high altitude trails, trails over passes and access routes to alpine huts have become more expensive to maintain or must be adapted to these new terrain features. In some cases new infrastructural elements such as creek crossings have to be constructed.

A survey of over 300 high alpine tourists and recreationists documented the importance of anticipating these increasing concerns about risk and safety correctly and of planning mitigating measures early on. One quarter of the respondents felt strongly that they wanted to avoid any risk, while the vast majority (71%) were risk-neutral, and only 4 per cent actually sought risk. Half of the respondents were highly uncertain about the concept of danger and risk in the alpine environment and many said that a further deterioration would lead them to stay away. These responses are based on a survey of regular visitors to the mountains, who are fairly familiar with the concepts and who contribute significantly to the economic basis of the region with their outlay for accommodation and other trip-related items.

The routes that should receive the major attention in terms of monitoring safety and improvements are those leading up to peaks or that offer considerable time savings, as it is these reasons that are the most likely to make hikers take risks.

The survey also showed that the preparation of maps is perceived to be primarily the responsibility of the public sector (provincial and federal governments), and to a lesser extent the domain of the tourism sector. On the other hand, the marking of trails and provision of signage is perceived to be the predominant responsibility of the mountaineering clubs. These clubs should also be responsible for guides, training and trail maintenance. One quarter of respondents suggested that the local communities be mainly responsible for trail maintenance and marking and other protective measures.

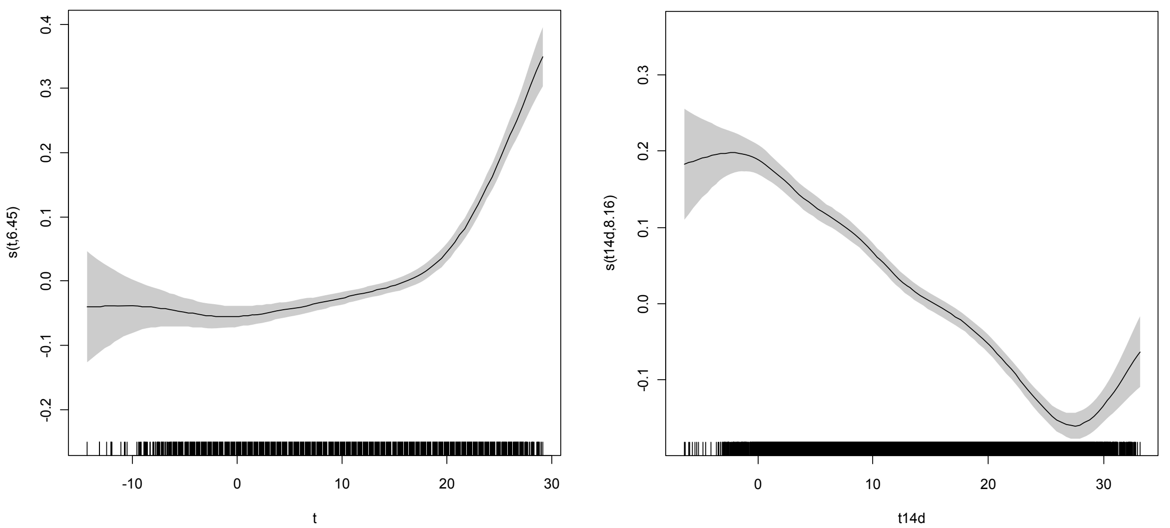
Finally, the perceived responsibility for major investments, including more sophisticated maintenance of trails, should spread evenly between the provinces (32%), the local communities (22%), the tourism sector (21%) and the federal government (18%).

2.7 StartClim2008.A: Impact of adaptation measures on the acute mortality risk due to extreme temperature in Vienna

The effect of extreme temperatures on health and especially on the acute mortality risk is well documented. Accordingly, Viennese mortality data (1990–2007) display the globally documented U-shaped association with temperature: the smallest number of daily deaths is seen at moderate temperatures. Beginning at daily mean temperatures of 18°C with minimum temperatures of 12°C or maximum temperatures of 20°C on the same day, the mortality risk increases linearly and steeply. The best predictor of the mortality risk due to cold is the average temperature over the previous weeks as depicted in figure 1b for the moving 14-day average: up to roughly 25°C a nearly linear decrease in the daily mortality risk is seen with increasing average temperatures. The effect of the cold is not an acute one and therefore cannot be discerned computationally from the overall seasonal effect of higher death rates in winter.

To better target adaptation measures it is essential to define the groups most in need. The acute effects of heat stress are more susceptible to warning messages and awareness raising campaigns than the more prolonged effects of the winter cold. Heat-related mortality is more pronounced in older persons and women. Inner city districts that suffer more from the urban heat island effect and “poorer“ districts (selected according to lower average real-estate prices) show a higher risk. The latter indicates socioeconomic influences that are not evident with the winter mortality.

The place of death (hospital, nursing home, own home) does not influence the relative risk of heat related mortality, but since most Viennese people die in hospitals this setting is most relevant for heat-related deaths in absolute values.



a) b)

Fig. 7 : Cubic splines (R-Package, library mgcv) showing the association between daily mortality risk and temperature (X axis). The Y axis represents the log (odds ratio); zero represents average risk, a change of 0.1 implies approximately a 10 per cent change in risk.

a) The mortality risk increases linearly with the average daily temperature from approximately 20°C onwards. At lower temperatures there is no clear correlation between mortality and temperature of the same day.

b) At lower temperatures the daily mortality risk correlates with the average temperature of the previous two weeks. Below a 14-day average of 28°C it increases linearly and strongly with decreasing temperatures.

We found no indication of differing heat sensitivity in the course of the summer. Since the heat-related mortality risk already increases at moderate temperatures where warning messages are not reasonable, it is impossible from the data to derive a threshold level at which acute measures should be triggered, but it seems reasonable to place such a threshold at a (predicted) nightly minimum temperature of 19°C. Warning messages should be directed to the health services and the general public. Based on the study findings they should be targeted towards elderly persons, women and socially deprived persons. The latter group still needs more precise definition. This could include persons with poor housing conditions or immigrants, in which case multilingual campaigns would be required. On the other hand it should be borne in mind that poorer migrants usually come from countries with hotter climates and they might be expected to have traditional behaviour adaptation strategies. Because of the lack of relevant data this question could not be considered in detail. Even if such data existed, there would probably not be a sufficient quantity for a meaningful conclusion to be drawn.

Fig. 8 : Relative risk of death on hot days (TMIN > 19°C) for different places of death: on hot days the relative risk is approximately 1.1 regardless of the place and is therefore approximately 10 per cent higher than on normal days.

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StartClim2008.A

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Figures and Tables

Figures

Tables

Annex

Subprojects of StartClim2003

These reports can be found on the StartClim2008-CD-ROM and on the StartClim website (www.austoclim.at/startclim/)

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 - University of Natural Resources and Applied Life Sciences
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 - University of Natural Resources and Applied Life Sciences
Andreas Frank, Petra Seibert

StartClim.5: Testing statistical downscaling techniques for their applicability to extreme events in Austria
Institute of Meteorology and Physics,
BOKU - University of Natural Resources and Applied Life Sciences
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
Center 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,
University of Natural Resources and Applied Life Sciences
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

These reports can be found on the StartClim2008-CD-ROM and on the StartClim website (www.austoclim.at/startclim/)

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: Contiunation 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

These reports can be found on the StartClim2008-CD-ROM and on the StartClim website (www.austoclim.at/startclim/)

StartClim2005.A1a: Impacts of temperature on mortality and morbidity in Vienna

Medical University of Vienna, Centre for Public Health, Institute of Environmantal Hygiene
Hanns Moshammer, Hans-Peter Hutter
Institute of Meteorology, BOKU
Andreas Frank, Thomas Gerersdorfer
Austrian Federal Intitute 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 Environmantal 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

These reports can be found on the StartClim2008-CD-ROM and on the StartClim website (www.austoclim.at/startclim/)

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

These reports can be found on the StartClim2008-CD-ROM and on the StartClim website (www.austoclim.at/startclim/)

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