StartClim2012

Adaptation to climate change in Austria: „Soils“

Final Report

November 2013

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Final Report

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

Contracting Parties

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

Administrative Coordination

Federal Environment Agency

Vienna, November 2013

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Adaptation to climate change in Austria: "Soils"

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Vienna, November 2013

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StartClim2012.C: Disturbance of forest stands and humus loss
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StartClim2012.D: To count with and on wood: adaptations of tools and data (German: Holz BZR)
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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
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Abstract

StartClim has been studying the topic of adaptation to climate change since 2008.

StartClim2012 focussed on “soils”, wood as a carbon reservoir, the climatology of snow lines in the Alpine region and, finally, a social science study addressed values and climate protection.

Soils are an essential and often underestimated basis of life for natural as well as human systems. They interact intensely with their environment (atmosphere, vegetation, water bodies, etc.) through matter and energy interchanges and react to climatic changes through severe alterations to essential soil processes and functions, such as the filter, buffer and transformation functions, the water balance compensating function, the production function and of course the habitat function for humans, animals and vegetation. Temperature increase and changes in precipitation (quantity, distribution and intensity) influence soil dynamics, mineralisation rate, water storage capacity and retentivity, biological activity in soils, and much more.

Soils can also be important sources and sinks of greenhouse gases, depending on their composition, vegetation cover, cultivation methods and other environmental factors. Thus they also play an important role in the context of climate protection.

At the same time the competition for soil as a limited resource is also intensifying in Austria. Growing land consumption by residential and commercial areas, the demand for biomass from agriculture and forestry, and habitat protection for rare plant species require the targeted inclusion of soil protection in spatial planning concepts. To achieve this, comprehensive soil data and adequate evaluation models are needed as tools.

Based on an extensive literature study (meta-study) it was shown that parameters currently assessed and measured, such as humus content (percentage C_{org}), net nitrogen mineralisation rates, bulk density, pH, microbial biomass, heavy metals, water holding capacity, in soil surveys or soil monitoring systems are not suitable, at least in their current form, for evaluating the effects of climate change on soil functions. This is mainly because of the inability to demonstrate the climate sensitivity of soil carbon dynamics, which is a key parameter in the evaluation of soil functions.

As for field parameters (ecological soil water balance, humus form, flooding dynamics, soil type, soil production class), an evaluation of climate sensitivity is not possible, since they each entail a classification comprising many factors and, moreover, are normally assessed only once. Thus information about change is lacking.

Forest soil is particularly significant as the largest organic carbon store. In temperate forests, for example, approx. 50% of the total carbon is stored in the soil. This amount results from inputs from leaf and root litter and outputs due to mineralisation, the breakdown of organic matter by microbial biomass. The removal or death of a tree reduces litter inputs but also increases mineralisation.

It is of special scientific and practical interest to know the reaction of forest soil to calamities such as windthrow, pests and diseases – events that could possibly be more frequent under altered climate conditions. Windthrow occurred in 2007 and 2009 on a site in the Upper Austrian Kalkalpen [Limestone Alps]. Through measurements of biomass and activity of fungal symbionts on the root, called mycorrhizas, it was shown that the soil in the 2007 windthrow area was virtually in the same condition as undisturbed forest soil, whereas in the 2009 windthrow area the mycorrhizas in the ingrowth bags were much less developed.

Climate change adaptation measures, especially soil protection, play an important role in agriculture. Cover cropping is a key measure for reducing erosion and preventing nitrate leaching to the groundwater. Around 33% of Austrian crop land is planted with cover crops after harvest, demonstrating that this measure has broad acceptance among Austrian farmers.

However, there are concerns that the cultivation of cover crops may lead to increased greenhouse gas emissions, raising questions about the effectiveness of this measure. Experiments on two sites with different climatic conditions (one in Lower Austria, one in Upper Austria) indicated that cover crops show small greenhouse gas emissions compared to fertilisation and tillage. Methane was negligible and carbon dioxide emissions were small because of the low soil temperatures between late autumn and spring. Provided that suitable cover crops were selected, nitrous oxide emissions were about one tenth of main crop emission levels, which is similar to emission levels of bare soil. Only mustard in pure stand showed enhanced emission levels. Important environmental drivers of greenhouse gas emissions were high soil water content (increase in nitrous oxide), dissolved organic carbon (increase in nitrous oxide and carbon dioxide) and plant nitrogen content (increase in nitrous oxide and carbon dioxide).

From these results it can be concluded that cover cropping is only of minor importance for greenhouse gas emissions from agricultural soils and may well be used as a climate change adaptation measure. Future agro-environmental programmes should promote mixed cultures, while avoiding mustard in pure stand.

Next to forest soil, wood is the most important carbon reservoir in forests. Cascaded use of wood is a suitable way of mitigating carbon dioxide emissions through the formation of a carbon storage pool in wood products. It is generally regarded as a cost-efficient and technically feasible climate change mitigation measure. Since an obligation to include changes in carbon pools in national greenhouse gas inventories was agreed at the 2011 United Nations Climate Change Conference in Durban for the reporting period of 2013, an adequate framework for meeting this obligation was elaborated in a study. The particular requirements for adaptation of the FOHOW model (a model simulating the entire forest-based sector, from wood resources over intermediates to end products) for assessment of carbon pools and missing data points were identified, and the tendential rise in the mean half-life of long-lasting wood products was observed. Regional assignments were conducted to assess wood quantities in single-family houses, and data on building dimensions were gathered. The wood use could thus be identified on the basis of model buildings, the Federal Register of Buildings and Dwellings and the share of timber in buildings.

The study of snow line climatology presented a completely different problem. Snow plays an important role within the Alpine region. Besides manifold implications for ecosystems (frost protection, water storage, snow damage, etc.) it has an enormous economic impact on winter tourism. The analysis of the change in snow line elevation over time within the last three decades in Europe shows some surprising results. It is only in summer that the snow line has shown a continuous upward trend. In all other seasons strong decadal variations, which can shift the snow line more than 150 m in either direction from the average conditions, characterise the 30-year mean. These variations have been most pronounced in western and southern Europe. Studies of snow reliability under climate change in Austria should definitely consider this.

Most important for winter tourism, the medians (50% of cases are above, 50% below) of winter snow lines differed more than 1000 m between the warmest and coldest areas in the Alpine region. The snow line median for north-eastern Austria is approximately 600 m; Italian ski resorts reach about 1200 m; and some French resorts are over 1500 m.

Climate mitigation and climate change adaptation are directly related to socio-cultural norms and values. Knowledge alone, e.g. of the threat posed by climate change, does not necessarily lead to climate-friendly behaviour. Individual and collective values (often held unconsciously) often influence behaviour. Some values appear to be a better source of motivation for environmentally and climate-friendly behaviour than others. Thus it is imperative to make values visible. To understand the evolution or change in values in society, indicators for measuring them are required.

A social science study explored these values by testing a process to identify and measure the shared values held by university staff and students. Interviews, surveys and working groups were used to identify eight values that are climate-relevant and meaningful for university members. These eight value statements were assessed using 76 validated indicators. The positive link between the eight values and the reduction in the carbon footprint, increased adaptability to climate chance and willingness to adapt to climate change is described.

It is recommended that these values and indicators be discussed (after adaptation to the different organisational contexts) and the possibility be studied of incorporating them in the BOKU sustainability report and sustainability strategy, the work of the BOKU Ethics Platform and the Working Group on Social Responsibility.

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. It is financed by a donor consortium consisting of ten institutions:

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

StartClim has been studying adaptation to climate change since 2008. It provides valuable contributions to the development and implementation of an Austrian strategy in this regard.

The StartClim2012 projects focussed on soils. Different aspects relevant to adaptation to climate change were explored. The projects investigated cover crops as a source or sink of soil greenhouse gas emissions, effects of climate change on soil functions, disturbance of forest stands and humus loss, cascaded use of wood as a climate change mitigation measure, snow line climatology within the Alpine region, and values as performance indicators for proactive climate protection.

The StartClim2012 report contains an overview of the results in German and English along with separately bound documentation, in which the individual projects are described in detail by the respective project teams. All reports and documents about StartClim2012 will be made available for download at http://www.austroclim.at/startclim, the StartClim website. A limited number of CDs with all StartClim reports and folders with a short summary will also be published.

2 StartClim2012A: Cover crops as a source or sink of soil greenhouse gas emissions?

Cover cropping is a key measure in the Austrian agro-environmental programme ÖPUL. Cover crops effectively prevent nitrate leaching to the groundwater and protect agricultural soils from erosion. Around 33% of Austrian crop land is planted with cover crops after harvest, demonstrating the broad acceptance of this measure among Austrian farmers.

The agro-environmental measures in future European agricultural policies will have to take particular account of their relevance to climate change mitigation and adaptation. The increasing frequency of extreme climatic events could result in a higher risk of soil erosion. Uncertainty regarding nitrogen management will increase because of drought and higher mean temperatures. These facts confirm the importance of cover cropping as an instrument for climate change adaptation in agriculture. However, a recent study evaluating the past ÖPUL programme revealed the risk of high gaseous nitrogen losses for certain cover crop species. As nitrous oxide is a greenhouse gas (GHG), more detailed information about emissions from cover cropped soils will help determine the meaningfulness of this adaptation measure.

In this project the influence of different cover crops on GHG emissions from agricultural soils in two climatically different sites (Lower Austria, Upper Austria) was studied. Four cover crop variants were compared with a bare soil control. The cover crop variants contained mustard, the most commonly used cover crop and the species with highest gaseous nitrogen losses reported in the study mentioned above, as well as three cover crop mixtures (phacelia-mustard, cress-mungo-radish, Alexandrian clover-mungo-phacelia). Soil GHG emission measurements were taken at critical moments when potentially high emissions were expected (onset of residue mineralisation, water saturation and thawing of soil in spring).

Nitrous oxide emissions between the end of cover crop growth (late autumn) and main crop seeding were generally low and between one and two magnitudes below peaks for emissions registered during the subsequent main crop at tillage and fertilisation (Fig. 1). On average, emissions related to cover cropping were 40 times lower (6.0 vs. 259.3 mg m^2 h^{-1}) than those during the main crop season. This is explained by strong emission peaks after organic nitrogen fertilisation and soil tillage and a rise in emissions with increasing soil temperature.

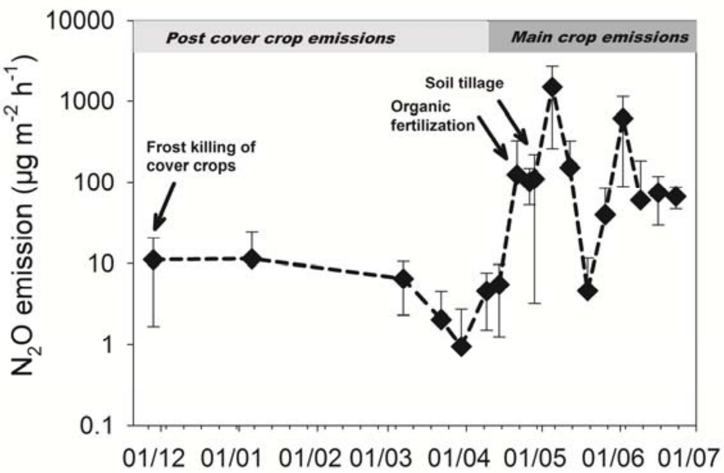

Fig. 1: Nitrous oxide emissions after a cover crop (example: mustard) and during the subsequent main crop (maize) at the experimental site in Pötting, Upper Austria. Note that the y axis has a logarithmic scale, i.e. emissions during the main crop period are, with one exception, between ten to hundred fold higher than in the post cover crop period.

Of the different cover crops, mustard showed the highest nitrous oxide emissions (Fig. 2) and they were substantially higher in particular at times of high average emissions (thawing and water saturated soil). Bare soil and cover crop mixtures did not show marked differences. The enhanced nitrous oxide emissions from mustard could be due to glucosinolate decomposition from mustard residues.

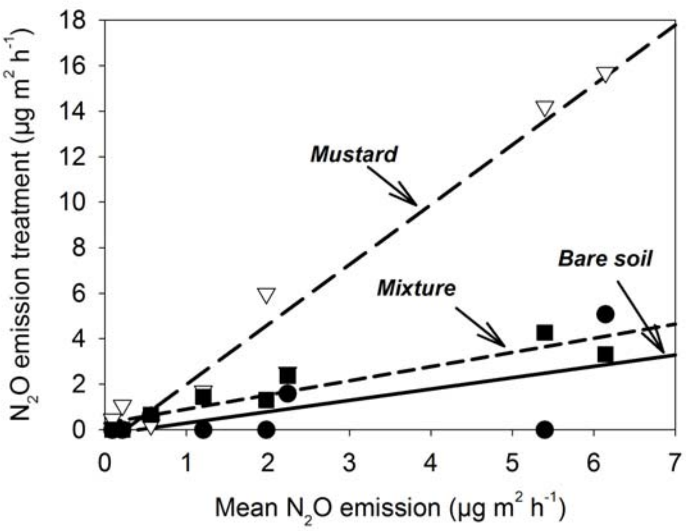

Fig. 2: Nitrous oxide emissions from mustard and cover crop mixtures (average of mustard-phacelia, cress-radish-phacelia and Alexandrian clover-mungo-phacelia) compared to bare soil for different average emissions.

Carbon dioxide emissions were also low between late autumns and spring because of low soil temperatures. Methane emissions were generally negligible. The higher carbon dioxide emissions from cover cropped plots indicated improved biological soil activity as a result of easily degradable green manure residues. While cover crops enrich the soil with organic matter, carbon dioxide emissions from bare soil have to be considered net losses of soil organic carbon.

Main environmental factors contributing to enhanced GHG emissions were identified, namely high soil water content (increased nitrous oxide emissions), high dissolved organic carbon content (increased nitrous oxide and carbon dioxide) and a high nitrogen content in the crop biomass (increased nitrous oxide and carbon dioxide).

The results showed that cover crops do not contribute substantially to GHG emissions from agricultural soils. Thus the advantages of cover cropping for climate change adaptation (erosion control, groundwater protection) clearly outweigh their role as GHG source. Future agro-environmental programmes should encourage cover crop mixtures but avoid pure stands of mustard. *Brassica* species are efficient cover crops and, when planted in mixtures with lower seeding density, do not result in higher GHG emissions. Enhanced carbon dioxide emissions are an indicator of a biologically active soil. With cover crops, carbon emissions into the atmosphere are compensated by carbon input, thereby helping to stabilise the organic matter balance in the soil.

3 StartClim2012.B: Effects of climate change on soil functions: metadata analysis

Soils interact intensively (substance and energy fluxes) with their environment (atmosphere, vegetation, water, etc.). Climate change is likely to have a significant impact on major soil processes and central soil functions – filter, buffer and transformation functions – and on the mediating function in respect to water balance, yield and as a habitat for plants, animals and human beings. Temperature increase and changes in precipitation quantity, distribution and intensity influence humus dynamics and soil mineralisation rates, water storage and retention capacity, biological activity within the soils and more. Indicators and soil parameters that describe these soil properties are important benchmarks for appraising the performance of soil functions.

At the same time, the competition for scarce soil resources is intensifying in Austria. Increasing land consumption for urban settlement and industry, the demand for biomass from agriculture and forestry and the protection of soils as a habitat for rare (plant) species demand the targeted integration of soil protection in land planning concepts. To this end, extensive soil information is needed along with suitable valuation models.

Soils have only recently been considered as subjects of protection and, apart from yield, soil functions have not been appraised to date. It was only in 2012 that an Austrian standard, ÖNORM L 1076, was published, followed by a background paper on methods for more comprehensive appraisal of soil functions (BMLFUW 2013).

The aim of this study was to determine whether the existing soil function appraisal methods are adequate to reflect changes in soil functions as a consequence of climate change. Furthermore it sought to identify possible (changed) interactions between individual soil functions and to illustrate these findings within a pilot area (Mühlviertel, Upper Austria). Recommendations for future proceedings, especially on the regional level, have been developed.

Our approach to this problem was to select those indicators and parameters for appraisal of soil functions (a) for which changes as a function of temperature and precipitation were thought plausible, (b) which are assessed or measured in a suitable way to reflect such changes, and (c) which are part of the standard parameter sets measured or assessed within soil surveys or monitoring schemes in Austria.

Some of these indicators and parameters react to changes in temperature and soil water conditions (a time horizon of 50 to 100 years was assumed), while others do not, and a third group react to changes but are not suitable for an assessment of change because of methodological problems:

a. potentially sensitive to climate change: pH, humus content (C_{org}), bulk density, water storage capacity, microbial biomass, land use
b. not sensitive to climate change: carbonate content, soil texture, particle size distribution (fine soil < 2mm), coarse fraction, clay content
c. potentially sensitive to climate change but unsuitable, because of assessment methods, for reflecting changes (one-time expert-based multifactorial assessment in the field): field classification of water balance, humus form, inundation dynamics, classification of soil value, soil type.

An extensive literature search (database: ScienceDirect, literature collections from BAW-IKT, BFW) for indicators and parameters from bullet point (a) and for nitrogen was conducted to determine expected or measurable qualitative and quantitative changes as a function of temperature and precipitation. The literature search was limited to the years 2005–2013 and the temperate climate zone. Only publications that fulfilled minimum standards with respect to test statistics were included and used for meta-analysis. The literature search was done using the Comprehensive Metaanalysis software package. For some factors, already published meta-analyses were used. For some parameters the literature base did not yield enough results for a meta-analysis. As far as possible, the results of the meta-analyses were compared with review paper results.

<u>Results</u>

Humus content (content C_{org}): Soil carbon loss is frequently predicted on the basis of theoretical considerations (increase in soil respiration [decrease in indicator Q_{10} for soil respiration with increasing temperature following the Arrhenius curve] and faster transformation of organic substance, soil carbon loss). It is also often postulated that an increase in net primary production due to climate change could mitigate this loss. Results from meta-analyses and review papers showed that definite conclusions cannot be drawn at present since a number of uncertainties influence the evaluation of the results (different temperature sensitivities of differently defined carbon pools, methodological problems in measuring decomposition rates, influence of further confounding factors such as changes in the water balance, atmospheric carbon dioxide concentration or land use, as well as uncertainties in balancing increasing carbon input because of increasing net primary production and increasing decomposition of organic substance in the soil). Since current versions of widely used models to predict soil carbon stocks are based on explicit assumptions (Q_{10}-curve) that do not reflect these uncertainties, the results of these models also have to be regarded as uncertain.

A meta-analysis of the change in soil carbon stocks over a period of more than ten years based on regional to national soil monitoring networks produced a heterogeneous picture. Although no significant changes were found, some studies found minor decreases in soil carbon, while others found no significant change. For that reason, the parameter soil carbon content could not be appraised either quantitatively or qualitatively.

According to our meta-analysis, the increase in net **nitrogen** mineralisation with increasing temperature is significant. Various meta-analyses show a positive correlation between net primary production and nitrogen supply and a slightly positive correlation with soil carbon stock.

A meta-analysis of the potential correlation between soil carbon content and **bulk density** showed a highly significant, slightly negative correlation. As a consequence this important input parameter for the calculation of water storage capacity cannot be used for appraisal of climate sensitivity. This is especially unfortunate because water storage capacity is an input variable for the appraisal of several soil (sub-)functions.

A potential change in **pH** as a function of temperature and precipitation could not be evaluated by meta-analysis because there are few publications on this subject. The existing publications found a slight increase or no changes.

Based on the results of our literature search an increase in **microbial biomass** with increasing temperature could be excluded, but a slight decrease could not be discounted. There were, however, highly significant changes in species groups within the microbial biomass.

A potential change in **heavy metal availability** as a function of temperature and precipitation could not be evaluated by meta-analysis because there are few publications on this subject. Some publications based on greenhouse or warming experiments indicated increased mobility of some heavy metals with increasing temperature or soil drought.

The following conclusions may therefore be drawn:

1. Our literature search found no quantitative proof of climate sensitivity for any of the primary parameters for the appraisal of soil functions. This was mainly due to the absence of quantitative proof of climate sensitivity of soil carbon, a central input parameter for the appraisal of many soil functions.
2. Field assessment parameters such as water balance, humus form, inundation dynamics, classification of soil value and soil type, could not be appraised in connection with climate sensitivity since they each entail a classification comprising many factors and, moreover, are normally assessed only once.

3. Soil function appraisal methods are not suitable in their current form for determining the effects of climate change on soil functions.
4. The inconsistent results found in respect to temperature sensitivity of (soil) carbon were due to the multitude of processes, which in turn are influenced by multiple factors, and also to the different methods and protocols used. Whereas standard protocols and methodologies have been developed in the course of the research on forest die-back norms so as to achieve better comparability of measurements, they do not exist in this research field.

Important parameters like soil respiration (factor Q10) are measured at only a few selected sites. It would be useful to introduce these parameters into the standard measuring set for existing soil monitoring and soil survey networks so as to broaden the database and include these parameters in respect to ecosystem types or (regional) political units.

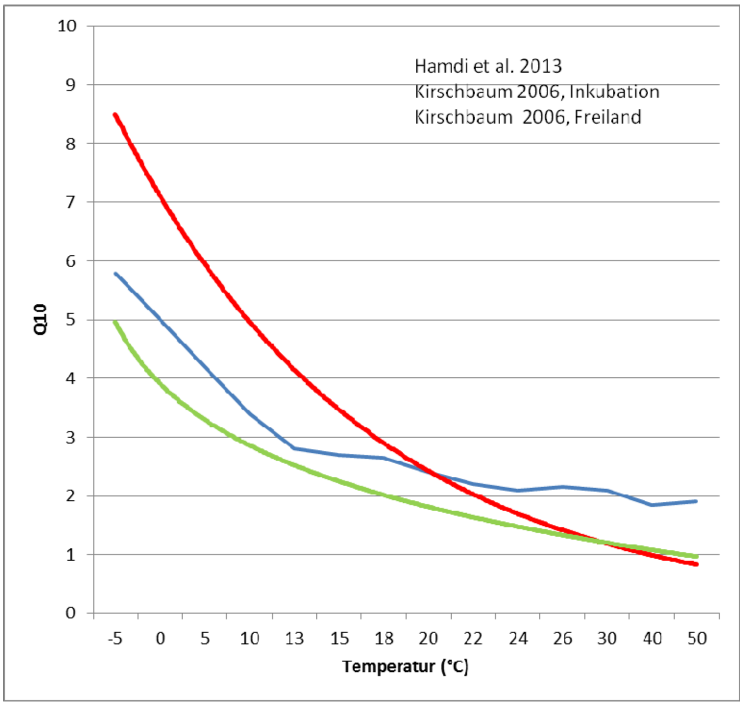

Fig. 3: Relationship between the Q10 factor and incubation temperature (Hamdi et al. 2013 mod., Kirschbaum 2006, mod.)

4 StartClim2012.C: Disturbance of forest stands and humus loss

Forest soils are the largest and most enduring storage pools for organic carbon worldwide. In temperate forests around 50% of the total carbon is stored in the soil. The amount depends oninputs from leaf and root litter and outputs, which in turn are influenced by the rate of mineralisation, i.e. the breakdown of organic matter by microorganisms, and by erosion. Recently it has been shown that biomass input from mycorrhizal fungal hyphae is also a major source for the formation of soil organic carbon.

Disturbances causing the loss of tree cover such as windthrow and bark beetle infestation also change the carbon dynamics in soils. Removal or death of a tree results, in the long term, in a decrease in litter inputs but also in an increase in mineralisation. The increase in mineralisation is due to changes in soil water content and soil temperature, which control microbial activity. In addition, as mycorrhizas are dependent on a carbon supply from the host trees, the death of the trees strongly decreases mycorrhiza activity, particularly that of the extramatrical mycelium growing in the soil. A decrease in mycorrhizal fungal activity allows the activity of saprotrophic fungi to increase and hence can also increase soil organic matter mineralisation. This increase in activity, known as the Gadgil effect, is regarded as an important mechanism behind the increase in mineralisation.

It is predicted that disturbances in the Alps due to windthrow and bark beetle will increase. Preliminary results have shown that ten years after a windthrow disturbance soil organic carbon stores decrease to almost 25% of the pre-disturbance levels. In StartClim project C, an investigation was carried out to attempt to determine the mechanisms behind this loss of soil organic carbon after disturbance.

The investigation was carried out at Höllengebirge, Attersee, in the Upper Austrian Kalkalpen [Limestone Alps] using the existing sites of the EU Intereg project "SicAlp". The sites are dominated by spruce and beech trees. The spruce stands were affected by large windthrows in 2007 and 2009, thus providing a pseudo-chronosequence to allow investigation of changes over time after disturbance. In forests both trees and ground vegetation have fungal symbionts on their root called mycorrhizas. The fine hyphae of these mycorrhizas form a large biomass in the soil. In this study, the hyphal biomass of the mycorrhizas was investigated from September 2012 in undisturbed forest and in the windthrow areas using ingrowth bags. These are bags with a fine mesh that allow hyphae to grow into them. A series of plots was established to simulate the effects of windthrow and permit separation of soil carbon dioxide efflux from the roots and fungal biomass (autotrophic respiration), and from breakdown of soil organic matter through mineralisation (heterotrophic respiration). In a trenching experiment, soil monoliths were isolated by digging a 50 cm deep trench and installing a plastic sheet. This treatment cut the carbon supply to the tree roots in the monoliths and prevents regrowth of the roots, thus removing autotrophic respiration. On the windthrow plots, carbon supply to the roots of the herbaceous vegetation and grass was decreased by clipping and removing the aboveground vegetation. In addition to the original work planned in the research proposal, i.e. the measurement of mycorrhizal hyphal biomass, a number of other measurements were carried out, including estimates of fungal and bacterial activity.

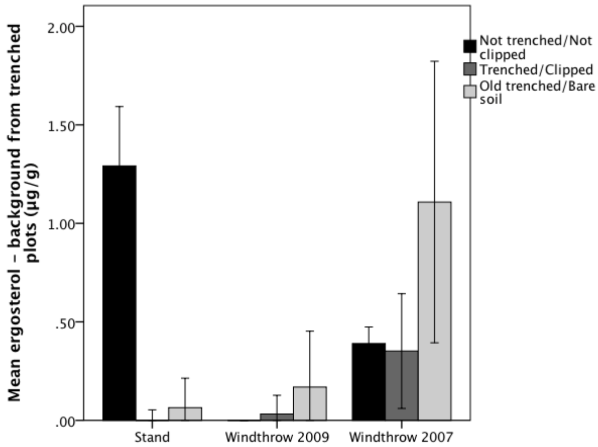

Fig. 4: Ergosterol values (i.e. approx. mycorrhiza biomass) on non-clipped/non-trenched, clipped/trenched, and old trenched/bare soil plots at the stand (control), 2009 windthrow and 2007 wind throw (mean ± SE).

The ingrowth bags were removed in July 2013, and the mycelium biomass in the bags was estimated by visual and ergosterol analysis (Fig. 4). Only in the 2009 windthrow was a significantly lower amount of mycelium found. No significant difference was found between the intact forest and the 2007 windthrow, although the ergosterol values were lower. Similarly, clipping at the 2007 windthrow did not affect the amount of total mycelium, which depended on the number of trees (Fig. 5), suggesting that fungal biomass recovered after the 2007 windthrow.

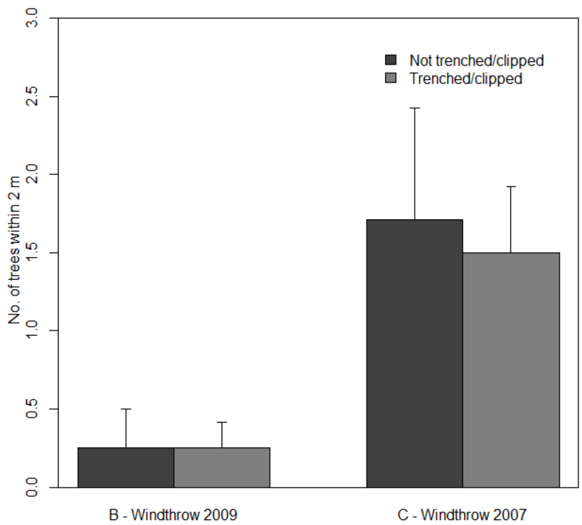

Fig. 5: Number of tree seedlings within 2 metres of the non-clipped/non-trenched, clipped/ trenched plots at the 2009 and 2007 windthrows (mean + SE).

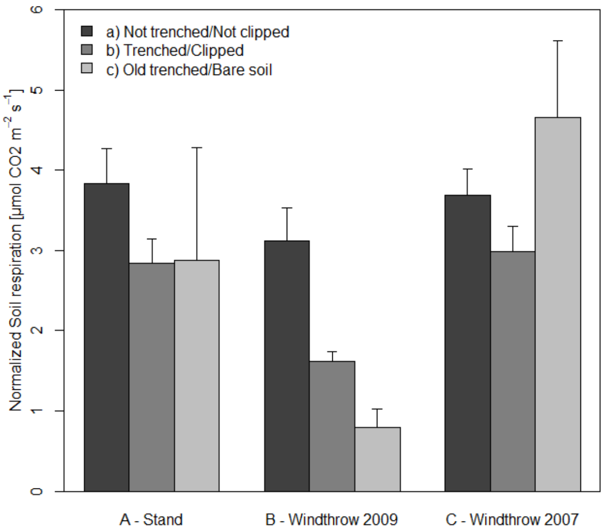

Fig. 6: Soil carbon dioxide efflux in intact and trenched/clipped plots in the forest stand and 2009 and 2007 windthrows (mean + SE).

Soil respiration decreased in the trenched and clipped plots in the intact forest and windthrows (Fig. 6). A comparison of the mean values of the non-trenched and trenched plots indicates that autotrophic respiration was about 30% of the total soil respiration in the stand, and a little less in the 2009 windthrow. The results indicate that root and fungal activity in the 2007 windthrow had recovered to the level found in the intact forest.

We studied the soil humus dynamics of a disturbed forest stand on a typical calcareous site in in the Kalkalpen [Limestone Alps] compared to nearby undisturbed stands. The work was carried out on patches of soil that had not been lost by erosion. As hypothesised, there were clear fluctuations in ectomycorrhizal biomass after windthrow, but the biomass recovered after several years and successful colonisation by tree seedlings took place. Loss of activity of the mycorrhizal hyphae and the onset of the postulated Gadgil effect could not be clearly shown, as there were a number of parallel events, such as changes in litter input and soil pH, which might mask direct biological effects. However, the work clearly showed that rapid regeneration of vegetation at the site, particularly tree seedlings, is vital for soil protection and restoration of soil biological activity. In addition, it is vital for measures to be undertaken to prevent the initial loss of soil due to erosion before (tree) vegetation can regrow.

5 StartClim2012.D: Counting on wood: adaptation of tools and data (German: Holz BZR)

The actual and useful life of wood can be extended beyond the period of forest turnover by the material use of forest biomass. A cascaded use of wood is therefore a useful way of improving the national greenhouse gas balance, as not only are the resources used efficiently, but also a carbon pool is implemented outside the forest. In the international literature this measure for avoiding greenhouse gas emissions is described as cost-effective and technically feasible, especially with regard to compensation of emissions from non-point sources, such as those from all kinds of transportation.

For the purpose of international accounting of carbon release and sequestration, the Production Approach for Harvested Wood Products (HWP) of Domestic Origin (PAD) was defined at the climate conference in Durban for use to abate carbon sequestered in harvested wood products.

In the course of the StartClim project basic principles were developed to meet Austria's commitment to report and offset emissions. In particular the possibilities for practical data improvement were reviewed as follows:

1. Identification of the need to adapt the FOHOW simulation model for future simulations and calculations of the carbon storage in HWP
2. Identification of the amount of wood used in one type of building (single-family house) and examination of the data integration in the Federal Register of Buildings and Dwellings
3. Involvement of the woodworking industry and examination of the development of a data trusteeship system

The business cycle statistics in production and numerous assumptions and translations of the data formed the basis for the creation of an input-output table showing the distribution of different uses of wood on the basis of the semi-finished products. This table was supplemented by further national statistics. The consistency of the generated data was checked by comparison with studies in other countries. Finally the available and comparable business cycle statistics were used to generate as lengthy a time series as possible. The period from 2002 to 2011 was systematically evaluated in respect of the wood use and a time series generated for that period. There was a distinct upward trend in the mean half-life (weighted according to amounts and type of utilisation). This is a quite remarkable development, as all calculation approaches for carbon storage in HWP to date have acted on the assumption of a static half-life. This increasing trend is the result of various factors, e.g. developments in technology, engineering and mechanical engineering. The development of society towards sustainable materials and a general reorientation of industry are further plausible reasons. Another possible hypothesis is that due to intensified competition between material and energetic use of the wood, there has been an increasing use of wood for long-term and high-quality applications.

It was also possible to identify the amount of wood used in single-family houses. The wood and timber products required for load-bearing elements in 27 single-family house models (walls, ceilings and roofs) were determined from records by Austrian carpentry companies and manufacturers of prefabricated houses. The individual data from the companies were made anonymous and statistically evaluated. The use of wood and timber products in the different buildings was broken down into the most common construction forms and related to the gross floor area of the houses. After calculating the results for all houses made of wood and all roof timbering in massive constructions for the period 1998 to 2008, it was extrapolated that between 1998 and 2008 about 3,000,000 m^3 wood and 750,000 m^3 of derived timber products were used as load-bearing elements.

This provides a further tool for improving data, especially historical data. In the medium term other construction forms and construction years could be included to make complete extrapolations on the basis of the Federal Register of Buildings and Dwellings. These extrapolations would provide an effective way of verifying the accuracy of international assumptions for modelling the historical HWP pools for Austria.

Only the involvement of the woodworking industry fell short of expectations. While the willingness of the industry to hand out data can be improved in the medium term, the impression was received that the available industrial data would not contribute to a significant improvement in the data. As acceptance by the industry for charging of HWPs is nevertheless important and a long-term improvement in data availability is essential, an information event might be useful after an initial estimation of its effect. An event of this type is planned for 2014 in cooperation with the Austrian Federal Environmental Agency.

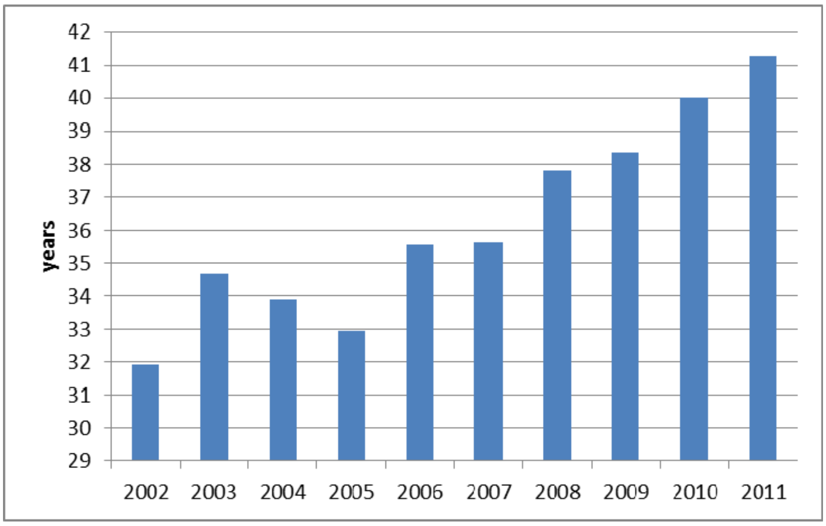

Fig. 7: Mean half-life (weighted by amount and utilisation) of wood products made in Austria

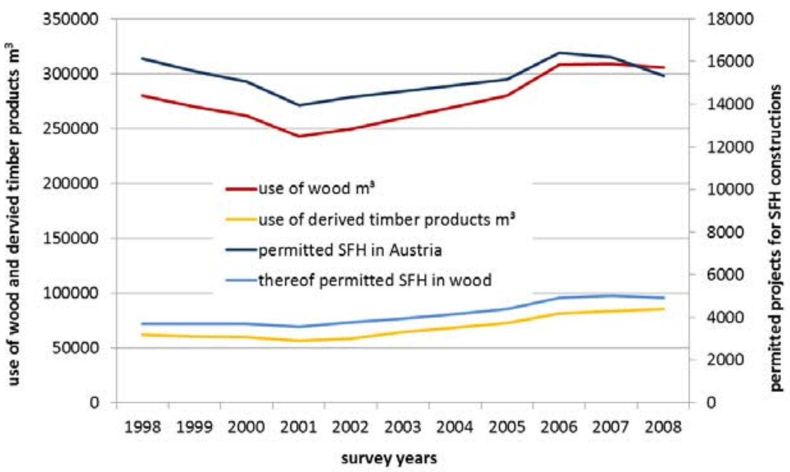

Fig. 8: Use of wood and derived timber products, and the total approved single-family houses (SFH) and wood buildings in the period of 1998– 2008

5 StartClim2012.E: Snow line climatology in the Alpine region derived from re-analysis data

Snow plays an important role in the Alpine region. Besides manifold implications for ecosystems (frost protection, water storage, snow damage, etc.) it has an enormous economic impact. A key factor for snow accumulation is the elevation at which precipitation changes from snow to rain (snow line). If the snow line is very high because of the temperature, there is no possibility of snow accumulation in lowlands and low mountain ranges. During spring and autumn this can lead to an increased flood risk because of a reduced buffering effect of snow.

The analysis of snow line elevation over the last three decades in Europe shows some surprising results:

- In Europe from 1979 to 2011, only in summer was there a continuous trend towards a higher snow line, as expected given the observed temperature increase for that period.
- In all other seasons strong decadal variations can be seen, most pronounced in western, central and southern Europe, but no trend.
- Decadal anomalies can shift the snow line up to 200 m in both directions (precipitation mass weighted) from average conditions within the 30-year period.
- Up to now the strongest decadal variations have been found in winter in the Balkan region and western France/Great Britain, but not in the Alpine region.
- The unexpectedly low snow line in autumn in the last decade is a central European phenomenon extending from eastern France to the Baltic states and from the Alps to southern Sweden.

The snow line in Europe during summer (Fig. 8) shows a clear latitude-dependent structure, with increasing elevations in the south (Fig. 8 top right). On the Iberian Peninsula and in Turkey, the elevation is 3600 m, and in northern Scandinavia the values reach 2000 m. In most parts of continental Europe the snow line increased steadily by 200 m between the 1980s and the 2000s. In the Alpine region this increase no doubt contributed to the massive glacier decline. Only some parts of the Iberian Peninsula and eastern France had lower snow lines in the 1990s.

These results are derived from the physically consistent calculation of the snow line at precipitation, based on the meteorological fields of the ERA-INTERIM re-analysis model for the period 1979–2011.

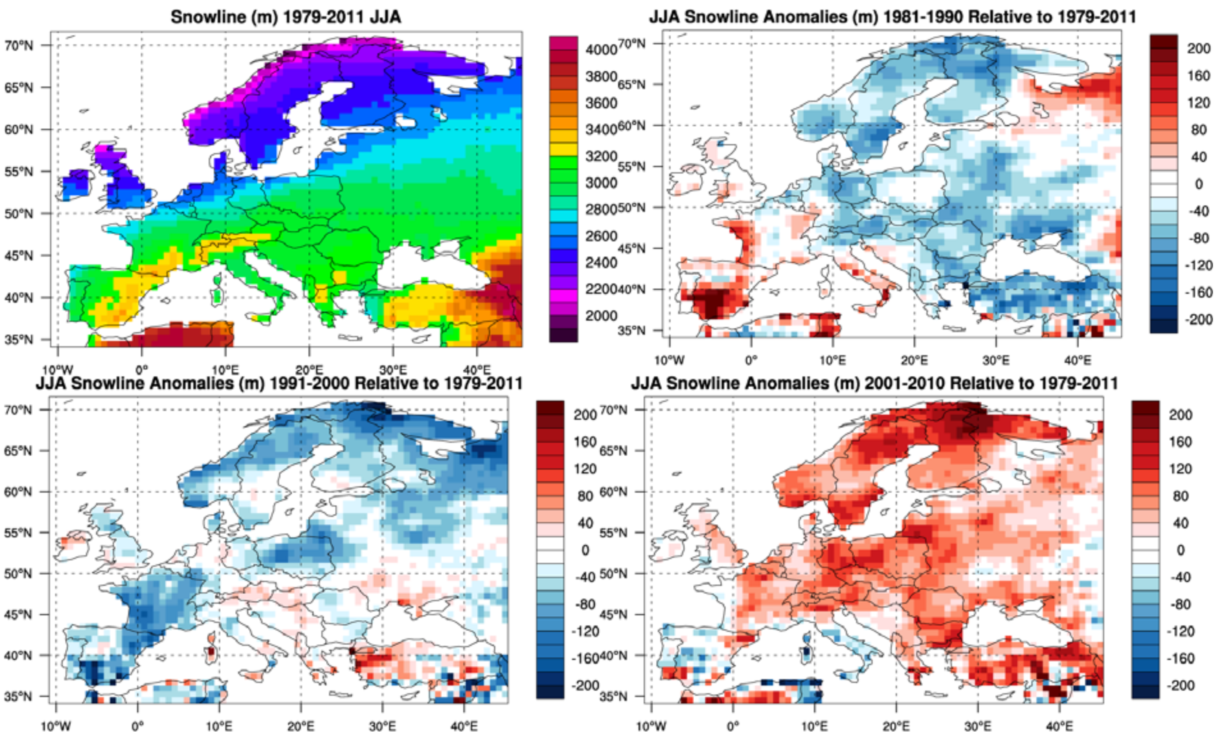

Fig. 9: Average snow line elevation (arithmetic mean) in summer (JJA) for the period 1979–2011 (top left), and the deviations from this average in the 1980s (top right), 1990s (bottom left) and 2000s (bottom right). All values are elevations in metres.

Especially in winter a clear regional differentiation within the Alpine region (Fig. 9) can be seen. The Alpine region can be separated in four sub-regions:

- continental
- Atlantic/continental
- Mediterranean/continental
- maritime

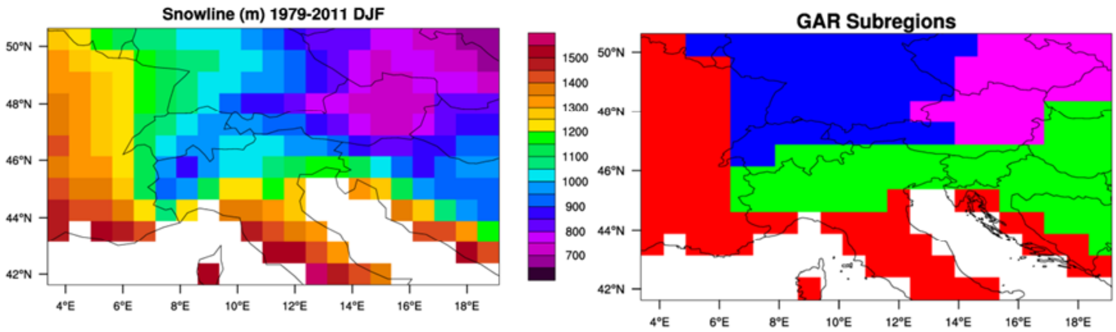

Fig. 10: Average snow line elevation (median) for winter (DJF) for the period 1979–2011 in the Alpine region (left) and sub-regions (right). Magenta = continental, blue = Atlantic/continental, green = Mediterranean/continental and red = maritime

The snow line has a distinct annual cycle in the Alpine region (Fig. 10). The magnitude is highest in the continental region and ranges from 500 m in February to 3100 m in July and August. In the maritime region the summer snow line also lies at 3100 m, with a minimum in February of 1300 m. In the two transition regions the winter minimum is 1000 m and the summer maximum 3000 m. The differences between the regions are greatest in winter, with 400 to 500 m lower snow line in the continental region than in the transition regions and up to 800 m lower in the maritime region. From this it can be estimated that the precipitationproducing air masses in the continental regions are approximately 5 degrees colder than in the maritime region and roughly 2 degrees colder than in the transition regions.

In the summer months the differences between the regions vanish, and between May and August the snow line is even slightly higher in the continental region than in the Atlantic/continental region. The main reason for this is the low temperature difference between the air masses in the Alpine region in summer. The high fraction of convective precipitation partly contributes to this.

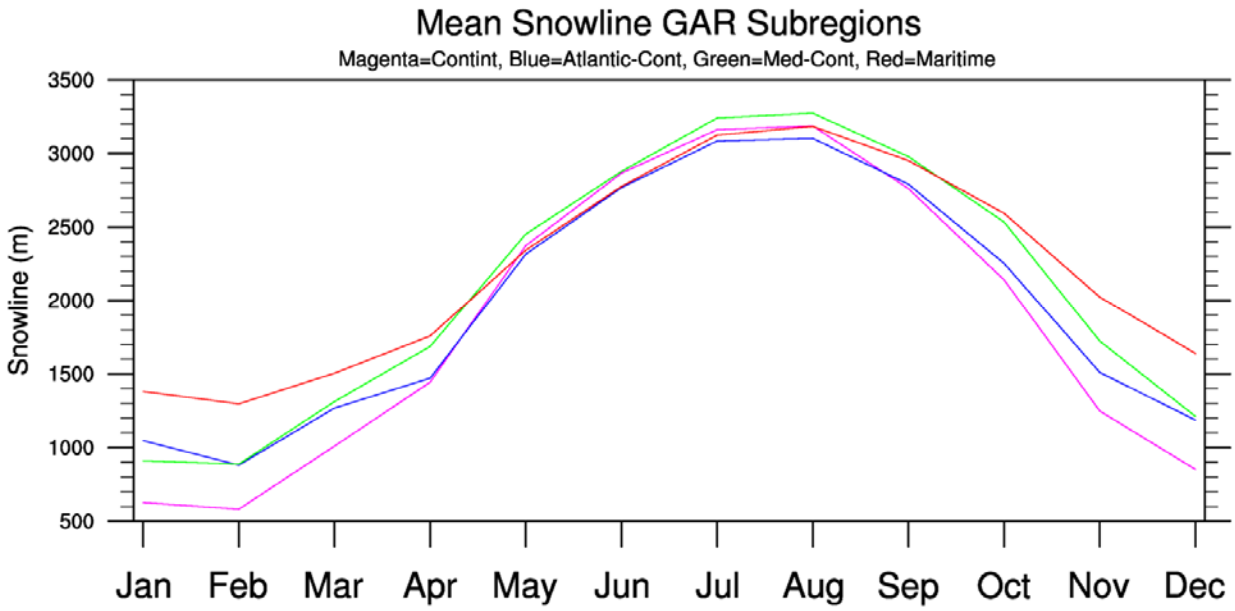

Fig. 11: Annual snow line cycle (1979–2011) averaged (mass weighted) for the four Alpine regions. In winter differences up to 900 m can be seen, with the lowest values in the continental region and highest in the maritime region. During summer the regional differences do not exceed 200 m.

One important insight of this study for winter tourism in Austria is the very high decadal variability in the winter snow line in Europe. Up to now the highest decadal variations have not occurred in the Alpine region but in the Balkans and Great Britain. These variations showed an increase of up to 150 m, which corresponds to an average temperature increase of 1°C. This natural variability increases the uncertainty in studies focusing on the snow reliability under climate change conditions.

6 StartClim2012. F: Values as performance indicators: towards proactive climate protection

Discussion on climate protection, sustainability and the adaptation to climate change is no longer a question merely of objective scientific data and facts. It is recognised today that the way in which individuals confront climate change and the extent to which they implement the corresponding strategies or make resources available for adaptation strongly depend on the socio-cultural environment and on individual or collective values.

Despite the fact that many people are very aware of environmental problems and the threats posed by climate change, this knowledge is not sufficient to motivate specific sustainable behaviour or observable reductions in greenhouse gas emissions. There is a conflict between social expectations, cultural conditioning and social values, which influences individuals' actions. For instance, KASSER et al. (2007) show that certain values have a significant influence on carbon footprint. A survey conducted in the USA on reasons for supporting climate-policy measures demonstrated that the reasons given had much less influence than the values and the political beliefs of the polled individuals.

In this project we investigated the importance and influence of individual values and those shared by members of a university (University of Natural Resources and Life Sciences, BOKU) on climate-relevant behaviour. Some values (e.g. universalism, self-determination, respect for nature) seemed to be a better source of motivation for environmental and climate-friendly measures than others, and exposing people to these values appeared to promote climate-friendly behaviour. Since sustainability is also an ethical challenge, there is a specific need to address socio-cultural values as guidelines for individuals and institutions and their work. Great progress towards sustainability could be made if these social-cultural values were better known and more verifiable, tangible and manageable.

Indicators are used by organisations to measure success or progress, thus contributing to target definition. In most cases, however, they focus on actual performance (e.g. number of publications) or survey non-sustainable figures (e.g. energy consumption or land use), and are therefore unsuitable for measuring climate protection or sustainability. There are few useful value-based indicators for sustainability to operationalise intrinsic ethical principles that are shared, practised or desired by the members of an organisation.

For this reason the important/meaningful values for BOKU members (employees and students) were identified, and value-based indicators for measuring these values developed. The overriding aim was to foster the inclusion of value-based indicators at different levels in the organisational culture of BOKU in order to document the *status quo* and the change in practised ethical principles in the organisation. This could be the first step towards strengthening institutional values, leading to more climate-friendly and sustainable behaviour. This research project had the following goals:

1. Identification of values important for BOKU members
2. Identification of values promoting a reduction in the carbon footprint and motivating other environmental-friendly activities
3. Development of indicators for measuring pro-sustainable values from step 2), and
4. Initiating discussion on the usefulness/relevance of a value-based assessment of the university.

A qualitative social research design was chosen, which involved 25 semi-structured interviews with BOKU employees and students. This was followed by a content and thematic analysis though categorisation, aggregation of individual values, comparison with literature and identification of associated meanings (goal 1 and 3). Through an online ranking 12 values were prioritised for validation in a participative workshop. In the workshop participants discussed results and created a common – i.e. inter-subjective – understanding of values, their meanings and corresponding indicators. In the context of this research, “values” were understood by the group as constructed and desirable states, principles or qualities.

A detailed comparison of literature with a subsequent correlation analysis of values and behaviour of the interviewees was carried out to identify the values motivating sustainability- and climate-friendly behaviour (goal 2). Finally, several discussion rounds with key players and relevant BOKU interest groups were held to talk about opportunities and obstacles and in particular the potential steps required for inclusion of the value-based indicators developed in strategic documents or rather established evaluation methods of the university (goal 4).

Fig. 12: In the validation workshop in March 2013 the values and indicators previously surveyed were further modified, corrected and validated by small groups of 4-5 BOKU members. They discussed the significance of each value both in the plenary session and in the small groups. An inter-subjective (quasi-objective) understanding of values is a prerequisite for deriving (objectively) verifiable indicators.

The main result were the eight BOKU pro-sustainability values (including corresponding indicators) that:

(i) were the most important BOKU values used for the joint development of a common, inter-subjective understanding

(ii) had a positive influence on climate behaviour as identified in the literature.

These eight values were:

- assumption of responsibility for the environment and protection, preservation and respect for nature for future generations
- critical thinking
- identification and pursuit of an individual path within and with BOKU
- integral and systemic reflection
- cooperation and teamwork
- networking and (interdisciplinary) exchange of know-how and experience
- friendly, cooperative working atmosphere and social interaction
- spirit of research, science and development of solutions to existing problems in society and in practice

Altogether there were 76 validated indicators for recording these values.

This explorative and pioneering study shows that it is possible to survey shared values in organisations and to develop value-based indicators for the university context. In addition, it shows that people who have the above-mentioned values will tend to act in a more pro-sustainability and climate-friendly manner. In the context of climate protection and the adaptation to climate change it is of particular interest that most of the BOKU values have a pro-social, open-to-change, holistic/integrative and ecologic-minded character.

The BOKU sustainability report, BOKU sustainability strategy, BOKU Ethics Platform, BOKU development plan and the Working Group on Social Responsibility were identified as potential groups and areas of application for these value-based indicators. The response and interest by the key players in these areas were very high. Steps are already being taken to further present these results within the organisation and organise follow-ups with major BOKU decision-makers.

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Annex

All following reports can be found on the StartClim2010-CD-ROM and on the StartClim website (www.austoclim.at/startclim/)

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