Extreme Events, Ecosystems And Just Transition

Final Report

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Contributions to StartClim2024

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University of Salzburg – Department of Geoinformatics – Z_GIS

StartClim2024.B: Pluvial and fluvial floods – how extreme will the new "normal" be if we fail to adapt adequately to climate-related changes
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StartClim2024.H: Comparison of the effects on soil water, yield and economics of two types of permanent montane grassland management
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Abstract

The StartClim research programme has been dedicated to the topic of adaptation to climate change since 2008. The projects in StartClim2024 addressed issues in various fields: effects of heatwaves on water temperature, pluvial and fluvial flooding, water harvesting practices, socially equitable energy and heating transition, climate-change adaptation, moorland restoration with carbon credits, vulnerable alpine infrastructure in climate change, and management intensities.

Analysis of the impact of heatwaves on surface and water temperature in the Neusiedler See – Seewinkel region using thermal satellite data (HOT)

The Neusiedler See is one of the few steppe lakes in Europe and its saline water, salt pans and extensive reed belt make it a unique ecosystem. The lake is fed primarily by precipitation, and the nearby salt pans regularly dry out. Extreme events such as heat and drought – intensified by climate change – threaten this fragile ecosystem. The HOT project investigated the impact of longer and more frequent heatwaves on land and water surfaces using thermal and optical satellite data. Time series analyses were conducted to assess temperature trends, changes in vegetation, and differences between protected and non-protected areas. The combination of satellite and meteorological data permitted comprehensive monitoring of surface and water temperatures and vegetation vitality – an important contribution to evaluating the impact of climate change and developing recovery and management strategies.

Between 1982 and 2024, the Neusiedler See region saw an increase in the frequency and duration of heatwaves, which now begin earlier in the year and last longer, highlighting the importance of continuous spatiotemporal monitoring. Analyses of vegetation indices and surface temperatures indicate that the negative impact on plant health following heatwaves is more pronounced in protected than in non-protected areas. This could be due to agricultural adaptation measures such as irrigation. More detailed analyses using higher-resolution data and extended time series could provide more precise insights in the future. The use of thermal satellite data permits the identification of spatial trends and their connection to changes in vegetation health.

Pluvial and fluvial floods – how extreme will the new “normal” be if we fail to adapt adequately to climate-related changes?

This research project examined how well disaster control authorities in Austrian municipalities and cities are prepared for the effects of possible future extreme flooding events. The central question was how aware local actors were of this issue and whether existing disaster control measures were sufficient. The natural hazards of river flooding, surface water, and the potential danger posed by mass movements were studied. Possible residual risks were also discussed with four municipalities in on-site workshops. Attention was paid to include municipalities of different sizes and characteristics (urban or rural) to ensure that the results were representative. The workshops were divided into two parts. The first part involved an assessment of the current situation. This was followed by a working session to consider climate-related changes in the risk situation that require modified or intensified coping measures.

In summary, the participating municipalities will face major challenges in their role as local disaster control authorities in the management of potential climate-induced increases in the complexity, frequency and intensity of natural hazard events.

One important consideration is the applicability of these results to other municipalities in Austria. While some of the results can be transferred directly, other aspects would have to be considered on a case-by-case basis.

Knowledge boost and interdisciplinary cooperation for water-harvesting practices in eastern Austria (WiBoo)

The aim of the WiBoo – Wissensboost und interdisziplinäre Kooperationen für Wasser-Ernte-Praktiken in Ostösterreich project was to promote collaboration between academic, public-sector and practical stakeholders in the application of water-harvesting practices. Through interviews and an interactive workshop with stakeholders from academia, administration and practice, the project identified needs and obstacles to the implementation of such practices and developed solutions with workshop participants.

Key challenges identified included the complexity and insufficient funding of the subsidy system, the risks for farmers in transitioning to water-efficient practices, barriers in knowledge transfer and the need for comprehensive inter-farm planning.

A central outcome of the project was recognition of the need for enhanced knowledge transfer and cooperation among the various stakeholders. Proposed solutions included establishing a competence centre, showcasing best-practice examples, initiating new pilot projects and simplifying approval procedures. Workshop participants suggested social media initiatives, training formats and field excursions as ways of fostering knowledge transfer, and initial collaborations were already formed.

The concept of financial recognition in future through biodiversity certificates was discussed. There was also interest in inter-farm measures such as retention ponds, though their implementation requires better legal and financial support. Regarding ÖPUL/GAEC (Good Agricultural and Environmental Conditions), a stronger focus on funding instruments for water retention in agriculture would be desirable. Additionally, an evaluation of CAP (Common Agricultural Policy) subsidies to improve their applicability for water-harvesting measures was deemed important.

Overall, the project demonstrated that the successful implementation of water-harvesting practices requires technical expertise, clear political frameworks and close collaboration among stakeholders from agricultural practice, administration and academia.

Scenarios for a socially equitable energy and heating transition in the residential building sector in Austria

The Austrian residential building sector accounts for around one-third of final energy consumption and 10 per cent of greenhouse gas emissions, making it crucial for achieving climate neutrality by 2040. As part of this project, the first system dynamics model for the Austrian residential building sector was developed, integrating the dynamics of the building stock, the transition to renewable heating systems, renovation behaviour and social aspects such as energy poverty.

Scenarios up to 2050 show that individual measures – such as subsidies or bans on fossil heating systems – would result in only minor emission reductions (<5%). Comprehensive policy packages that include subsidies, stricter regulations, mandatory phase-out of fossil heating systems and the expansion of renewable energy could reduce emissions by up to 59 per cent. However, complete decarbonization by 2040 appears out of reach without additional measures, on account of long lead times and slow transformation processes within the building stock.

Ambitious climate policies could slightly increase energy poverty in the short term (+0.1–0.3%) unless targeted social compensation measures are implemented. The analysis highlighted three key policy levers:

1. early and decisive phase-out of fossil heating systems
2. significant expansion of comprehensive building renovations with strong incentives and mandatory standards
3. socially balanced measures (e.g., income-based subsidies, targeted compensation mechanisms) to ensure fairness and societal acceptance.

The model could serve as a basis for future refinements and scenario analyses, providing policymakers with a dynamic tool for developing and simulating effective and socially equitable strategies for decarbonizing Austria's residential building sector.

System dynamics analysis of climate change adaptation scenarios in Austria to achieve the SDGs – identifying dynamics, interactions and potential synergies

The ongoing climate crisis and its increasingly noticeable impact pose a significant challenge to achieving sustainable development in line with the Sustainable Development Goals (SDGs). This project aimed to study the impact of climate change and adaptation measures in context of the SDGs and to analyse the interactions, dynamics and trends. The focus was on the agricultural sector, which is particularly affected by climate change. Three different climate scenarios – two adaptation scenarios, along with the expansion of organic farming and the reduction of land consumption, were simulated using the iSD-AT system dynamics model. This method made possible an aggregated analysis with particular emphasis on the interaction between socio-economic and ecological goals. Additionally, an expert workshop validated and complemented the model results by discussing the findings and identifying relevant dynamics not captured by the model. The results indicated a climate-related intensification of agriculture, reflected in higher water consumption and increased use of mineral fertilizers. Preserving agricultural land boosted overall agricultural production and countered the general trend of a decline in agricultural employment but increased pressure to reduce greenhouse gas (GHG) emissions in the sector. A shift to organic farming could mitigate this negative environmental impact, though it would come with the trade-off of reduced yield per hectare. Beyond the dynamics revealed in the model results, the expert workshop highlighted social aspects, such as the impact on food prices and long-term yield and income security. The findings demonstrated that key dynamics and interactions can be effectively represented at this aggregated modelling level. Future coupling with detailed bottom-up sector models could further combine the strengths of both approaches.

Peatland restoration with carbon credits: what contribution can voluntary regional carbon markets make?

With nearly 1 million tons of CO_2 equivalents, drained peatlands in Austria represent a significant source of greenhouse gas emissions. Through rewetting, drained organic soils have the potential to revert from a source of emissions to a store of greenhouse gases. Voluntary carbon markets could support this. In Austria, too, voluntary CO_2 certificates are regularly discussed in the context of peatland restoration but have not yet been implemented.

The pioneering projects MoorFutures in Germany and max.moor in Switzerland demonstrate the potential of compensation standards for peatland restoration, but also the limitations of this instrument. In both countries, the sale of offset certificates has nevertheless made it possible to finance nine and ten projects, respectively, for the restoration of peatlands with private capital over the past ten years. A comparison of the two standards revealed similarities but also a number of differences. Essentially, the countries use different governance models: (1) calculation of GHG savings based on the GEST approach in Germany vs. a pragmatic approach in Switzerland; (2) the project sponsor and certificate provider are the same organization at MoorFutures, while max.moor uses an external certificate provider as an intermediary; (3) MoorFutures sells certificates to private individuals and companies, while max.moor sells exclusively to companies; (4) the principle of regionality plays a much greater role in the sale of MoorFutures.

Both approaches are currently being discussed in Austria. As part of the EU LIFE AMooRe project, the Swiss model is already being implemented in a selected pilot project with an external certificate provider. In some provinces, fundamental aspects similar to the MoorFutures model have been considered, but no decisions have yet been reached. Landowners are very interested in CO_2 certificates as an additional source of income, but in practice this depends on many details. The demand from businesses for voluntary certificates is difficult to estimate, but it is likely to be concentrated among SMEs rather than large companies.

Vulnerable alpine infrastructure in the context of climate change: raising awareness of natural areas

Climate change has long become a tangible reality in the Alps. Glaciers are retreating, extreme weather events are increasing and permafrost is thawing. As a result, alpine natural hazard events are becoming more frequent. Debris flows, rockfalls, and landslides are increasingly damaging the alpine hiking and mountain trail network and pose a growing risk to the safety of hikers. At the same time, drier summers and winters with little snow are extending the hiking season, placing additional pressure on trail infrastructure. For those responsible for trail maintenance – particularly trained trail wardens – this means a rising demand for comprehensive monitoring and complex maintenance measures. This is where the tools and methods of av.geo.clim come into play. Using a digital reporting form, trail wardens and trained observers can systematically record natural hazard potential and events in the field. Through structured evaluation pathways, these observations can be classified and translated into a cartographic representation showing current natural hazards with elevated risk potential. This would offer a robust basis for decision-making for trail managers – and an easily accessible tool for hikers to identify risks early and act responsibly. In addition, interactive StoryMaps have been developed to convey basic knowledge about hiking, natural alpine hazards and climate change in an accessible form, especially for novice and less experienced mountaineers. By integrating information, prevention and protection, av.geo.clim makes a sustainable contribution to safety in alpine regions – helping ensure that mountain landscapes remain accessible and enjoyable, even in the face of climate change.

Comparison of the effects on soil water, yield and economics of two types of permanent montane grassland management

Permanent grassland, especially in mountainous regions, plays a central role in Austria in cultural land preservation and sustainable food production. Because of the climate and weather, permanent grassland fields in lowland regions are more intensively managed (> three cuts per year) than fields in topographically or climatically less favourable regions. In montane altitudes north of the main alpine ridge, only two cuts are sometimes possible, with inclusive and aftermath grazing in autumn. Because of climate change, particularly in mountainous regions, the temperature has increased in recent decades with the result that vegetation often begins earlier and lasts longer. Precipitation is increasing in northwest Austria but decreasing in southeastern regions. This project studied an actively managed grassland farm in western Upper Styria to determine the degree to which the longer vegetation period influences yield and whether additional management could increase it. In view of the fact that the more intensive management variant also involves additional work, the economic impact needs to be analysed.

Intensified management did not reduce the availability of soil water on this humid grassland site. In two of the four observation periods, the potential yield was higher with intensive than with semi-intensive management. The two periods with higher yield under intensive management had more precipitation and seepage water, but higher yield was achieved with semi-intensive management in the two periods with lower precipitation. In general, the yield on this site was influenced not by water but by energy, and the increase depended to a large extent on the weather and cutting times. At the same time, no economic benefit was identified from the higher yields achieved through intensive management.

Because of the limited data, further research is required to determine whether three-cut management on a humid mid-alpine site is economically and environmentally sustainable. More vegetation periods need to be studied to verify the existing findings.

The StartClim research programme

The StartClim climate research programme is a flexible instrument. Because of the short project duration and annual choice of project topics, it can react quickly to topical aspects of climate and climate change. Since 2008, StartClim has been dedicated to studying aspects related to adaptation to climate change. Since StartClim2012, the goal of the programme has been to provide scientific support for Austria's national adaptation strategy.

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- Austrian Federal Ministry of Education, Science and Research
- Austrian Federal Ministry of Climate Action, Environment, Energy, Mobility, Innovation and Technology
- Klima- und Energiefonds
- Federal Province of Upper Austria

The StartClim2024 subprojects presented here address various aspects of relevance to climate-change adaptation in Austria.

This summary report describes the results of the subprojects in a concise and generally understandable manner. It is also available in German. The detailed reports of the individual subprojects are compiled in a separate anthology, which, like the subprojects, is available electronically on the StartClim website (https://startclim.at/startseite). Additionally, a limited-edition folder containing a brief summary of the results will be produced.

StartClim2024.A: Analysis of the impact of heatwaves on surface and water temperature in the Neusiedler See – Seewinkel region using thermal satellite data (HOT)

Climate change is resulting in heatwaves of increasing frequency and intensity, significantly impacting the unique and ecologically important landscape of the Neusiedler See – Seewinkel region in Austria. The HOT project demonstrated how thermal satellite data can be used to monitor this impact over time. By analysing land surface temperature, vegetation vitality and meteorological trends, the project aimed to better understand the spatial and temporal characteristics of heatwaves and their effects on both protected and non-protected landscapes.

Methodology

The study integrated long-term meteorological data from GeoSphere Austria with freely available thermal (Landsat 8) and optical (Sentinel-2) satellite imagery. Heatwaves were defined as periods where air temperatures reached at least 30°C for three or more consecutive days.

The project focused on the most significant heatwaves between 2015 and 2024, analysing various land cover types across ten selected sites – five within protected areas and five in non-protected areas. The selected sites shared the same land cover typology: non-protected areas were characterized by higher agricultural use, while protected areas featured more forests and wetlands.

This approach allowed for a comparative analysis of how heatwaves affect different landscapes, providing valuable insights into the resilience of protected ecosystems versus those under agricultural use.

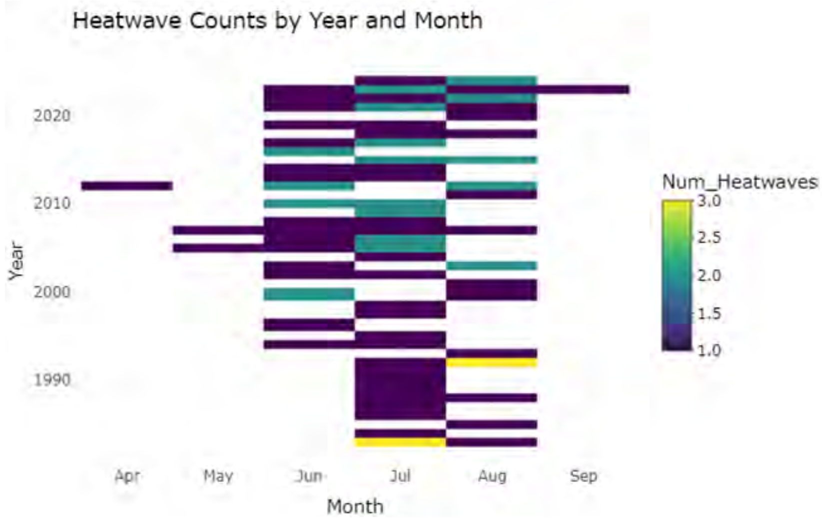

Fig. 1: *Number of heatwaves per year and month from 1982 to 2024 in the Neusiedler See – Seewinkel region*

Using the cloud-based platform Google Earth Engine (GEE), land surface temperature was calculated through the analysis of thermal satellite data and corrected as a function of vegetation cover. The land surface temperature data is available in GEE at a resolution of 100 m but may contain gaps or errors, particularly over water bodies, including salt pans or cloudy areas. This is due to the quality filtering and processing of surface reflectance in GEE, where low-quality or non-usable pixels are often excluded.

To address this, cloud masks were applied and unrealistic values filtered out. This made it possible to create reliable time series for various land cover classes in protected and non-protected areas, as well as around weather stations, illustrating how these areas warm or cool over time.

The results were cross-validated with other data sources, field study observations and feedback from local stakeholders to ensure quality and reliability. This approach provided robust insight into the thermal dynamics of the region and the impact of heatwaves on different landscapes.

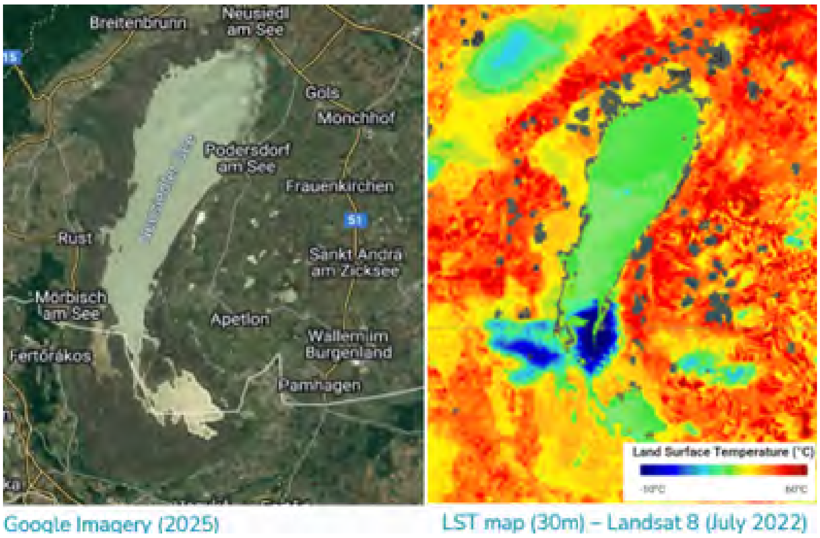

Fig. 2: *Optical satellite image and thermal map of surface temperature for July 2022 over the Neusiedler See. The thermal map highlights temperatures ranging from –10°C to 60°C, with hotspots shown in orange to red. Cloud-contaminated areas appear blue, and data gaps are represented in grey.*

Results

- Increasing frequency and duration of heatwaves: The long-term meteorological analysis for the Neusiedler See region confirmed a steady increase in the frequency and temporal distribution of heatwaves from 1982 to 2024. Heatwaves can now begin earlier in the year – sometimes as early as April – and extend into September. This highlights the importance of spatial and temporal monitoring of such extreme heat events.
- Vegetation stress in protected vs. non-protected areas: Satellite-based vegetation indicators revealed that plants in protected areas often showed stronger signs of heat stress than those in non-protected areas. Forests and wetlands, in particular, tended to be more sensitive to heatwaves. A possible explanation is that non-protected areas such as agricultural land benefit from irrigation and other land management practices that mitigate the effects of extreme heat.
- Surface temperature differences: There were also significant differences in surface temperatures between protected and non-protected areas. Non-protected areas tended to be hotter during heatwaves, often reaching temperatures of 30°C to 45°C. Protected areas remained relatively cooler, with soil temperatures ranging from 20°C to 45°C, due to denser vegetation and lower land-use intensity. In the protected areas of the Neusiedler See, natural grasslands, wetlands, water bodies and some agricultural fields are the dominant types of land cover. During heatwaves, these areas exhibited a smaller increase in surface temperature than in non-protected areas. Natural vegetation and wetlands, in particular, responded more moderately to heatwaves, probably due to higher soil moisture and less intensive land use. Conversely, non-protected areas are characterized by vineyards, non-irrigated croplands, pastures and more fragmented agricultural landscapes. These areas showed higher surface temperatures, probably due to the absence of the cooling effect of dense vegetation or nearby bodies of water. This pattern was observed consistently throughout the thermal time series, confirming that both land-use intensity and land-cover type significantly influence how much areas warm during extreme events

Conclusion

The HOT project explored the use of thermal earth observation data to assess the impact of heatwaves and to demonstrate its value for analysing large-scale trends, despite limitations in resolution. Initial patterns in vegetation responses to heatwaves were identified, highlighting the potential of this approach for future research using higher-resolution data and longer observation periods. Additionally, the project revealed challenges in evaluating the adaptability of protected areas to heatwaves. Feedback from stakeholders emphasized that even ecosystems in warmer climates are vulnerable to recurring heatwaves, underscoring the need for targeted adaptation strategies.

StartClim2024.B: Pluvial and fluvial floods – how extreme will the new "normal" be if we fail to adapt adequately to climate-related changes?

Objective

This research project examined how well disaster control authorities in Austrian municipalities and cities are prepared for the effects of possible future extreme flooding events. The central question was how aware local actors were of this issue and whether existing disaster control measures were sufficient. The considerations included the natural hazards of river flooding, surface water and the potential danger posed by mass movements. Possible residual risks were also discussed.

Approach

The issues were addressed with **four municipalities** in a series of **on-site workshops**. When **selecting** the **municipalities**, care was taken to represent as **broad a spectrum** as possible of the **potential natural hazards** affecting Austrian municipalities. Both urban and rural municipalities were recruited. It was particularly important that the natural hazards under consideration posed a certain degree of risk in these municipalities (see table). All participating municipalities were affected to a greater or lesser extent by the intense rainfall and subsequent flooding in September 2024.

	imprint		natural hazard			
Municipality	urban	rural	fluvial flooding	pluvial flooding	residual risk	landslides
Stockerau (Lower Austria)	x		x	x	x	
Grein an der Donau (Upper Austria)	x	x	x	x	x	x
Saxen (Upper Austria)		x	x	x	x	x
Rohrbach an der Lafnitz (Styria)		x	x	x	x	x

Fig. 3: *List of participating municipalities, including information on the characteristics and potential impact of various natural hazards*

During the telephone calls to arrange dates for the workshops, initial technical questions were discussed with representatives of the respective municipalities (mayors, heads of building authorities, etc.) and information on the existing situation was obtained. This permitted targeted preparation for the on-site appointments, during which municipality-specific features were identified.

The workshops were divided into two sections: "Status Quo" and "Looking to the Future". The second section of the workshop looked at climate-related issues that could lead to a possible change in the occurrence of natural hazards or require a change in the way they are managed.

Results

The participating municipalities have detailed knowledge of past flood events, heavy rainfall, mudslides and landslides. The policymakers are aware of the areas susceptible to river flooding as provided by state GIS systems. Based on this and past flooding, they built up their **assessment** of the **risks** to the **status quo**. Three of the four municipalities knew of the additional areas susceptible to pluvial and fluvial flood events as provided by HORA 3.0, but lacked the awareness to actively use them. In the fourth municipality, HORA 3.0 was unknown. Only the results from the earlier HORA system were known there, but they were deemed inapplicable to the local situation and were therefore ignored by policymakers.

With regard to **available resources** for dealing with natural hazards, the picture was consistently uniform. Material resources such as emergency vehicles, communication equipment, barriers and sandbags, were considered scarce but sufficient. Human resources, both at the municipal office/town hall and in the volunteer fire departments, had often been insufficient in the past. Operational management sometimes depended on a small number of people in the community, and expertise and experience from past events were also concentrated in just a few individuals.

Based on climate-related changes in the distribution and intensity of precipitation, **modified future hazard scenarios** for the municipalities were jointly developed. All four municipalities had perceived an increase in heavy precipitation in recent years and they all feared an increase in combinations of pluvial and fluvial events in future, and hence an intensification and increase in pluvial-dominated events. An example of this was a dangerous scenario that almost occurred in the city of Stockerau in September 2024, namely a combination of major flooding of the Danube (in the HQ100 range) with the resultant backflow into the Göllersbach and Senningbach tributaries, which would then be hit by flood waves from these waters as a result of heavy rainfall in the catchment areas. This would completely overload the protection system, with far-reaching, catastrophic and unmanageable flooding.

Based on the changed risk scenarios, the degree to which the participating municipalities were equipped for hazard prevention and incident management **in the future** was assessed. The picture was consistent across all municipalities. A more frequent occurrence of hazardous events as a result of pluvial and fluvial flooding or mudslides would place a heavy strain on municipal finances. The cost of the necessary clean-up and repair work would be prohibitive. There would also be limitations in terms of human resources. The day-to-day business of the municipalities would be limited because of the necessary rest periods after intensive operations. A more diverse team of qualified people would be needed, but this would be difficult to achieve because of staff turnover, limited course availability and high costs.

In **summary**, as local disaster control authorities, the participating municipalities face **major challenges** in coping with a potential climate-induced increase in the complexity, frequency and intensity of natural hazards. Insufficient municipal funding and staff shortages are limiting factors in this regard. Both preventively and in the event of an incident, personnel, technical and financial support is needed from higher levels (districts, provinces, federal government) and external partners (fire department, police). This begins with promoting the creation of disaster control plans and extends to controlling roadblocks and providing support in the event of necessary evacuations.

StartClim2024.C: Enhancing knowledge and interdisciplinary cooperation for agricultural water harvesting in eastern Austria

The increasing periods of drought in eastern Austria pose major challenges for agriculture, local authorities and regional policymakers in dealing with water scarcity. At the same time, there is a wealth of scientific and practical knowledge on how water can be effectively retained and used on agricultural land. This project was initiated to promote the implementation of such measures and, in particular, to strengthen cooperation between academic, public-sector and practical stakeholders. The Weinviertel region served as a pilot region to connect existing initiatives and develop new solutions. An interdisciplinary approach was used to identify obstacles, pool knowledge and find concrete actions.

Method

To provide a scientific basis for the further project steps, a literature review was conducted, analysing international and national studies on water harvesting in agriculture. This was followed by eleven semi-structured interviews with key actors from various sectors to gain insight into existing experiences, needs and obstacles to the implementation of agricultural water-harvesting measures. The results of the interviews were clustered thematically and summarized in five central questions. These questions formed the basis for an interactive workshop with academics, farmers and representatives of local, regional and national administrations. The workshop was designed to enable active participation and prioritization of topics by the participants. The most important challenges were discussed in small groups, and solutions were developed jointly. In addition, participants presented their own project ideas for discussion. The results of the interviews and the workshop were compared with existing funding programmes, and recommendations for further consideration were elaborated.

Results

The literature review summarized land-management methods and farming practices that help to retain water in agricultural soils and reduce erosion. Measures such as mulching, no-till farming and intercropping reduce evaporation and surface runoff, while humus formation increases the soil's water-holding capacity. Agroforestry systems and hedges contribute by reducing wind speed and improving the microclimate. The introduction of drought-tolerant plant species such as sorghum or the adoption of winter cereals offer further adaptation options. Structural solutions, such as the creation of retention ponds, green drainage channels and buffer strips, help to retain water and prevent erosion. In combination with contour ploughing and methods such as keyline-design structural measures can form an effective basis for water-management planning on agricultural land.

In several interviews, the current financial viability and funding instruments for agricultural water-harvesting measures were mentioned as key obstacles to implementation. Among other things, the interviewed stakeholders stressed lack of clarity regarding funding opportunities that support water harvesting, but also the limited funding for very small measures (minimum funding thresholds) and measures that affect or are shared by several farms (e.g., the construction of retention basins). When adopting water-saving management, farmers are exposed to considerable financial risks, which are only insufficiently mitigated by funding mechanisms. Therefore, well-equipped incentive systems -to promote the implementation of measures. The authorities expressed a need for concrete information on the effectiveness of water-saving measures in order to be able to provide farmers with sound technical advice on the transition to such practices. This requires increased exchange between associations and academic, public-sector and practical stakeholders, and also improved needs-based knowledge transfer and outreach and awareness-raising among farmers.

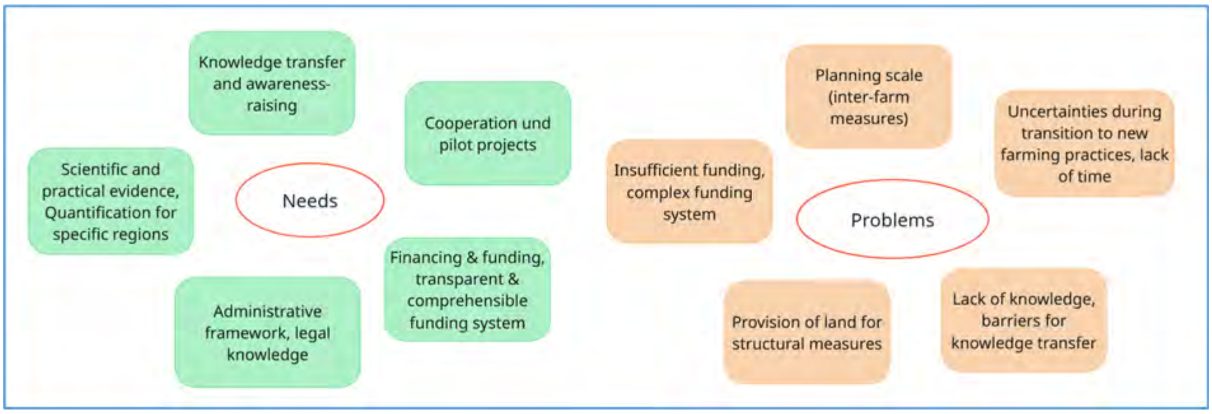

Fig. 4: *Analysis of needs and problems of stakeholders regarding further implementation of water-harvesting measures in agriculture*

The workshop addressed the problem areas identified in the interviews and explored them in greater depth. The participants emphasized the topics of knowledge transfer, persuasion and strengthening the exchange between academic and practical stakeholders. Social media initiatives such as Farmfluencer could be used to reach young farmers, while excursions and competitions could showcase good practices and encourage replication. Exchange between researchers and practical stakeholders should be strengthened through long-term networks and digital platforms. In addition, the need to establish a central competence centre for water-harvesting research or to use existing structures was emphasized. The financial compensation of ecosystem services, e.g. through biodiversity certificates, was discussed, as many workshop participants agreed on the need for additional financial resources alongside existing support programmes in order to meet future challenges. However, concepts such as biodiversity certificates require close cooperation between farmers, national and EU institutions and, above all, relevant stakeholders from industry. Small retention ponds should be researched and studied more intensively to evaluate their effectiveness. In general, inter-farm solutions for water retention were considered particularly effective, but require an appropriate legal framework. Concrete project ideas such as drainage infiltration on suitable soils, excursion programmes with agricultural schools and dialogue formats with land users were also discussed.

Funding programmes such as ÖPUL and GLÖZ already include measures that have a positive impact on the water balance. However, the focus of all these measures is not explicitly on water retention and is aimed more at soil erosion or biodiversity. These programmes should therefore be adjusted to better support water retention as a means of adapting to climate change. Regulations allowing greater flexibility after the creation of new landscape elements could also increase their attractiveness. The CAP support programme for sector- and project-related measures includes water-harvesting measures, but funding is limited, meaning that not every project can be supported. It is recommended to review the support system to identify potential barriers and to enable a coordinating governmental agency to be established in each federal province to provide an overview of the various support options connecting the water and agriculture sector.

Conclusion

Overall, the project showed that an integrated, cooperative approach is necessary to implement large-scale water-harvesting measures. Successful implementation requires not only technical solutions, but also suitable framework conditions, joint steps by the various stakeholders, targeted funding, broad knowledge exchange and the visibility of showcase projects that inspire confidence and demonstrate the effectiveness of the solutions.

StartClim2024.D: Scenarios for a socially equitable energy and heating transition in the residential building sector in Austria

Buildings account for approximately one-third of final energy consumption and 10% of total greenhouse gas emissions. At the same time, housing is a fundamental social need: poorly designed climate policies risk exacerbating energy poverty and social inequalities.

This project developed a system dynamics (SD) model to explore how Austria's residential building sector can achieve climate neutrality while maintaining social equity.

The SD model dynamically simulated:

- building stock development: new construction, demolition and renovations
- heating systems: transition from fossil fuels to renewable heating technologies
- energy efficiency improvements: through deep building renovations
- energy costs and energy poverty: impact on different household types
- policy feedback loops: how climate pressure and social acceptance influence policy measures

Households were divided into twelve groups (building type, ownership/rental, income level), enabling the model to analyse in detail who pays, who benefits and who may be left behind.

Policy scenarios examined

Eight policy scenarios were tested against a baseline scenario:

- economic incentives (ECO1–ECO4): subsidies, CO_2 pricing, improved cost pass-through for rental properties and awareness campaigns
- decarbonization of heating systems (GHG1–GHG3): bans on fossil heating systems, restrictions on replacement installations and expansion of renewable heating sources
- comprehensive policy package: a combination of all measures for maximum impact

Key findings

- Renovation rates:
  - Subsidies and CO_2 pricing would increase renovation rates by +9–10%
  - Improved cost pass-through for landlords would boost renovations by +35%
  - Heating bans alone would have virtually no effect on renovation dynamics
- Energy consumption:
  - Total energy consumption in the building sector would decrease by –3.4% by 2050 under the all-policies scenario
  - Efficiency gains would result from renovations and the use of more energy-efficient heat pumps
- Greenhouse gas emissions:
  - The comprehensive policy package would reduce emissions by 59% compared to the baseline scenario
  - Individual measures would have only a minor effect (<5% reduction)
  - Climate neutrality cannot be achieved by 2050, even with comprehensive measures, due to slow renewal of building stock and heating systems

- Energy poverty:
  - CO_2 pricing and heating bans would slightly increase energy poverty (+0.1–0.3%)
  - Subsidies would help mitigate the burden but would not fully offset it

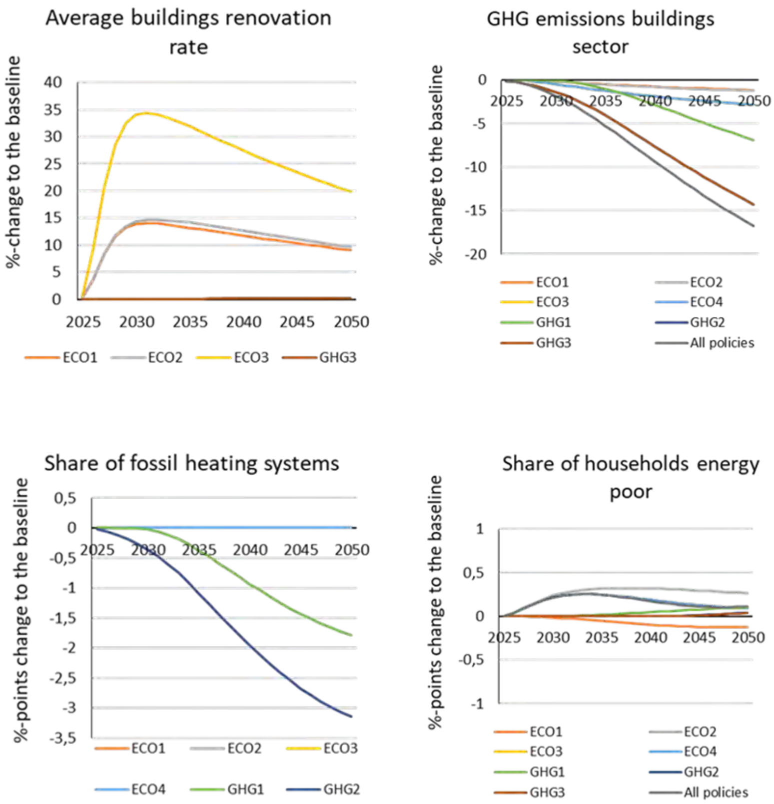

Fig. 5: *Effects of different policy measures on renovation rates, greenhouse gas emissions, the share of fossil heating systems, and the share of energy-poor households*

Political implications

- Comprehensive policy packages are essential: significant emission reductions can be achieved only through a combination of subsidies, regulations, heating bans and the expansion of renewable heating systems.
- Early and decisive action is crucial: a rapid phase-out of fossil heating systems and a massive scale-up of deep building renovations are key to meeting the 2040 climate targets.
- Social mitigation is key: targeted compensation measures are necessary to prevent energy poverty and ensure societal acceptance.
- Holistic approach: climate policy must address technical measures, behavioural responses and social impacts together.

Conclusion

This project provided the first SD model for Austria's residential building sector, integrating climate protection and social equity. The results highlight the need for transformative changes: 1) a rapid phase-out of fossil heating systems, 2) significant scale-up of comprehensive renovations, and 3) socially balanced measures to protect low-income households.

StartClim2024.E: System dynamics analysis of climate change adaptation scenarios to achieve the SDGs in Austria – identifying dynamics, interactions and potential synergies

Introduction

Climate change and its noticeable impact demand urgent action. Agenda 2030, with its Sustainable Development Goals (SDGs), promotes a holistic approach to sustainable development, making it essential to evaluate adaptation measures in the context of the SDGs. Since agriculture is particularly affected by changes in precipitation and temperature, this project examined the impact on specific SDG indicators of climate change and selected adaptation measures in agriculture.

Objectives and approach

The project analysed how climate-change impact and adaptation strategies in Austria's agricultural sector influence the achievement of the SDGs. The focus was on long-term trends, dynamics and potential trade-offs and synergies. The iSD-AT system dynamics model was used, and an expert workshop was conducted. The model provided aggregated trends for indicators under various climate-change and adaptation scenarios, while the workshop explored the impact of specific measures on the SDGs in detail. This allowed for the identification of effects not captured by the iSD-AT model, contributing to the validation of the model results.

Results of the expert workshop

During the workshop, participants discussed the impact on the SDGs of three measures from Austria's current adaptation strategy: adaptation of agricultural management (conservative vs. organic farming), sustainable management, restoration and conservation of soil, and evaluation of the site suitability of crops and cultivation of climate-adapted crops. With the exception of SDG14 (Life Below Water), SDG16 (Peace), and SDG17 (Partnerships), all other SDGs were identified as potentially affected. The strategies were linked to more resource-efficient use of irrigation, fertilizers and pesticides. Social aspects, such as rising food prices and increasing inequalities, were also highlighted. Conflicting dynamics were identified, for example climate-resilient crops, which reduce resource use but could lead to intensification if cultivated on previously unsuitable land.

Scenarios and selected indicators for modelling

The model looked at two climate scenarios to analyse the effects of changing temperature and precipitation on sustainability goals. Both scenarios assumed an average warming of 0.6°C per decade, supplemented by a dry and a wet precipitation scenario. A counterfactual scenario, assuming no changes in temperature or precipitation after 2023 was added to isolate socio-economic trends. Two adaptation policy scenarios were also simulated: a gradual expansion of organic farming to 100% by 2050 (Pol_Orga), and a limitation of land consumption beyond the 2023 level (Pol_Land). The selected indicators focused on relevant SDGs in the agricultural sector, including irrigated cropland and water use (SDG6), mineral nitrogen fertilizer use and agricultural land (SDG15), average yield and total production (SDG2), real GDP and employment in agriculture (SDG8) and greenhouse gas emissions (SDG13).

Results from the iSD-AT model

Studies for Austria show that changes in precipitation and temperature could lead to either intensification or extensification of agriculture, depending on the region, through higher or lower use of mineral nitrogen fertilizers and more intensive irrigation. In the iSD-AT model, an overall intensification effect was observed. Based on the assumed precipitation, water use for irrigation (SDG6) will increase by over 15% by 2050 in the dry scenario compared to 2023. Since the model did not account for water scarcity, this increase would have to take account of regional and local situations. The increase in yield potential and the resulting intensification would also affect ecological goals, such as reducing greenhouse gas emissions (SDG13) and preserving biodiversity (SDG15).

Adaptation strategies could counteract negative developments and enhance positive ones but could also result in trade-offs. Preserving agricultural land would increase total production (SDG2) and thus food security but would also raise water use and mineral nitrogen fertilizer application, leading to higher greenhouse gas emissions. Expanding organic farming could mitigate these effects, positively impacting climate protection and biodiversity, but would also result in lower yields per hectare (SDG2). Both measures would positively influence agricultural employment (SDG8), counteracting the general decline. A combination of both measures (Pol_Comb) could balance the positive and negative effects of each adaptation strategy.

Conclusions and outlook

The study demonstrated that macroeconomic models like iSD-AT provide valuable insights into the systemic effects of climate-adaptation measures and their interactions with the SDGs. Synergies, between organic farming and climate protection (SDG13), for example, and trade-offs, such as lower yields and potential impact on food security (SDG2), were identified. Experts emphasized the importance of a reduction in resource use and social equity. Future studies should include interactions between several adaptation measures and allow more regionally differentiated results by coupling the iSD-AT with sector-specific models.

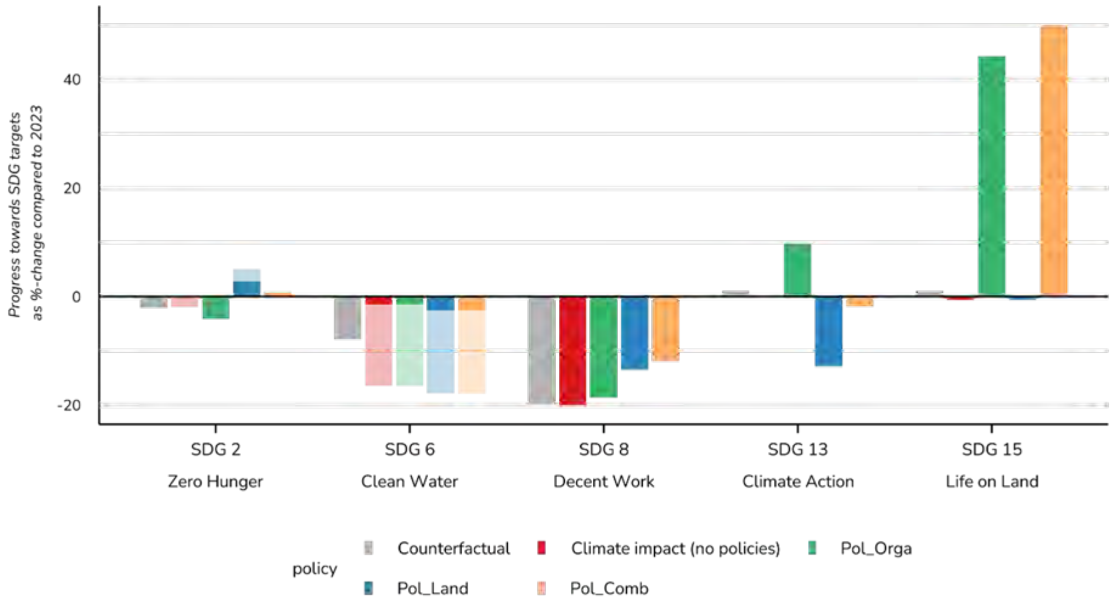

Fig. 6: *Impact of different scenarios on the progress of selected SDGs; selected indicators were assigned to the SDGs and their development weighted equally.*

StartClim2024.F: Peatland restoration with carbon credits: what contribution can voluntary regional carbon markets make?

Drained peatlands are a potentially significant source of greenhouse gas emissions in Austria. Drained organic soils in Austria emit almost 1 million tons of CO_2 equivalents annually, 1.4% of total Austrian greenhouse gas emissions in 2022. Rewetting could potentially revert them from producing significant emissions to acting as a store for greenhouse gases. Removing CO_2 from the atmosphere makes an essential contribution to achieving climate policy goals. Voluntary carbon markets are an important instrument to support this. By purchasing compensation certificates, companies and private individuals could finance projects that avoid the emission of greenhouse gases elsewhere or actively remove CO_2 from the atmosphere and bind it in the long term. Despite the growing interest of the private sector in offset certificates, voluntary carbon markets for peatland restoration have so far been established only in a few countries. In Austria, too, voluntary CO_2 certificates are regularly mentioned in the context of peatland restoration but have not yet been implemented.

Comparison of voluntary CO_2 certificates for peatland restoration

The market for voluntary CO_2 certificates has undergone rapid developments in recent years. Global demand for offset certificates has skyrocketed since 2016, exceeding 2 billion dollars for the first time in 2021. In 2023, however, this demand fell sharply, mainly because of negative reports in the media about the effectiveness of forest protection projects, which caused considerable uncertainty regarding the quality and integrity of the projects and thus the voluntary CO_2 certificates. To address these uncertainties, the European Union adopted a regulation in December 2024 to create an EU-wide framework for the certification of permanent CO_2 removal, carbon farming and CO_2 storage in products (CRCF regulation). In the area of peatland rewetting, activities can be certified that (i) aim to partially or completely rewet organic soils, (ii) increase the water level on the land, or (iii) promote paludiculture. These activities must exist for at least ten years.

The proposed methodology for the certification of peatland rewetting projects was based on the experience with existing certificate systems. The comparison of the MoorFutures standard in the Germany and max.moor in Switzerland showed similarities but also differences between the respective standards. Essentially, the countries use different governance models: (1) calculation of GHG savings based on the GEST approach in Germany vs. a pragmatic calculation approach in Switzerland; (2) project developers and certificate providers are the same organization at MoorFutures, while max.moor uses an external certificate provider as an intermediary; (3) MoorFutures sells certificates to private individuals and companies, while max.moor sells exclusively to companies; (4) the principle of regionality plays a much greater role in the sale of MoorFutures.

Implementation in Austria

In Austria, as part of the strategic LIFE project AMooRe, the creation of attractive conditions for CO_2 storage through the renaturation of moors is being considered. The current discussion in Austria largely reflects the experiences in Germany and Switzerland. All experts agree that the German GEST approach is not suitable for the small-scale moorland areas in Austria and they are therefore orienting themselves towards the pragmatic Swiss model. Essentially, two financing models are currently being considered: (1) a purely private-sector model and (2) initial financing through public funds.

The pilot project currently being implemented is based on a further development of the max.moor standard, which already takes into account compatibility with the requirements of the CRCF regulation. The privately financed pilot project in Austria has no equivalent in the models of other European countries. The approach is also very demanding, making it unlikely that it can be applied to a large number of renaturation projects in Austria. The alternative model, in which the public sector provides support for the high initial investments through public funds, is still under discussion. In order to establish this model in Austria in the long term, the federal provinces would have to take a more active role, which is not currently the case. This could be done through the establishment of nature conservation funds at the provincial level or through project management by other public institutions. Almost all experts in Austria also want projects to have a strong regional focus. It is questionable whether this can be implemented in the models currently under discussion in the same way as the German model, where certificates are sold to hundreds of private individuals. Here, too, the Austrian approach will probably be based more on the Swiss model and focus primarily on companies as buyers. It is currently difficult to assess the level of interest among companies in supporting such projects in Austria. Large companies are primarily focused on reducing their own emissions, with only a marginal interest in offsetting remaining emissions. In any case, experience from other compensation systems shows that small and medium-sized companies are more likely candidates for such projects. However, similar challenges also arise on the supply side.

Landowners continue to show great interest in CO_2 certificates as an additional source of income, but implementation is proving difficult and will ultimately depend on many details.

Conclusion

CO_2 certificates are a useful tool for financing the restoration of peatlands. In view of the number of peatland areas currently involved in the LIFE project AMooRe, it is to be hoped that at least the same number of compensation projects can be realized in Austria in the coming years as have been successfully implemented in Germany and Switzerland under the MoorFutures and max.moor standards.

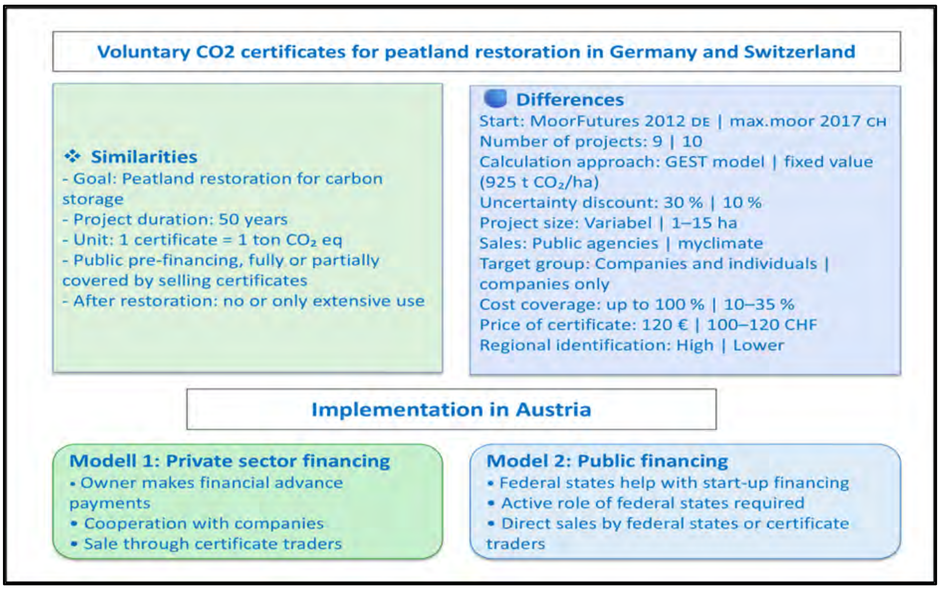

Fig. 7: *Voluntary CO_2 certificates for peatland restoration in Germany, Switzerland and Austria*

StartClim2024.G: av.geo.clim – Vulnerable alpine infrastructure in the context of climate change: raising awareness of natural areas

Climate change is leaving increasingly visible traces in the alpine region, with far-reaching consequences for ecosystems, infrastructure and recreational users in mountain areas. Rising temperatures, more frequent heavy rainfall and thawing permafrost are increasing and transforming natural hazards such as rockfalls, debris flows and landslides. At the same time, the number of recreation seekers is increasing, especially in climatically favourable high-altitude zones, intensifying the pressure on alpine landscapes and exposing hikers to greater risks. Parallel to these developments, there are fewer voluntary trail wardens to inspect and maintain trails. Maintenance requirements are rising due to climate-related damage and intensive use, while human resources are dwindling. The combined effects of climate change, more frequent extreme events and structural shifts in voluntary engagement present new challenges for trail management. This creates an urgent need for sustainable risk-awareness, maintenance and organizational strategies in the alpine region.

The av.geo.clim project addressed these challenges. Its aim was to develop practice-oriented methods for scientifically reliable assessment of natural hazards along mountain trails. In addition, accessible scientific communication sought to promote broader understanding of hazard causes, dynamics and their link to climate change. To design targeted measures, three main stakeholder groups were identified: recreational users, trail wardens and experts.

A key element – assessment pathways

A central component of the project was the integration of structured, easy-to-use but scientifically robust assessment pathways for the classification of natural hazards. These pathways would support experts in systematically recording and evaluating hazard situations on trails and in making decisions on maintenance, safety measures and communication. They would provide voluntary wardens with a practical tool for better assessment and documentation and at the same time offer trail users new ways of accessing information on natural hazards and their impact.

A digital survey form for field data collection

A digital survey form was developed to facilitate the application of these assessment pathways. It was accessible via a simple web link and could be completed directly in a browser without additional software or prior knowledge. Trail wardens could use it to collect targeted information relevant for hazard assessment, such as the type of process, soil conditions or previous events. Particular attention was given to ease of use: many questions are supplemented with help texts or images, enabling even less experienced users to obtain meaningful assessments. These additional resources also serve as a form of sensitization, enhancing awareness of alpine hazards such as rockfalls, landslides or debris flows.

Application of data – hazard potential mapping

The collected field data formed the basis for a hazard potential map that highlighted vulnerable trail sections. The map indicated where increased attention was required, whether action was needed, and how hazards were distributed. It would support policymakers and trail managers in planning and implementing measures more effectively. Hikers could also benefit by accessing useful information to support risk-minimizing decisions, thereby reducing accident potential. Such maps would not only provide practical guidance but would also raise awareness of natural hazards and the broader impact of climate change. An extended version of the map will integrate potential developments up to 2045. Comparisons between current and projected conditions reveal significant changes: glaciers and permafrost zones are retreating upward, while hazard zones are shifting in extent, intensity and frequency. Interested users could further explore these developments through the interactive StoryMaps produced in the project.

Knowledge transfer – digital StoryMaps

Beyond data collection, a second project focus was knowledge transfer. The question was how to reach groups not directly involved in trail maintenance, such as hikers, hut visitors or day tourists. For this purpose, digital StoryMaps were developed. These provide not only basic hiking information but also explanations of natural hazards, their causes, dynamics and climatic drivers. Content is designed to be accessible and visually appealing, featuring animations, explanatory texts and concrete examples from the study area. Particular emphasis is placed on the link between climate change and natural hazards: What does thawing permafrost mean? Why are heavy rainfall events becoming more frequent? And how do these processes affect trail conditions?

Feedback, ideas, and exchange – expert workshop

An expert workshop was organized to situate the project in practice and gather valuable feedback. It confirmed that the project addresses highly relevant tasks and provides benefits for many stakeholders. Discussions highlighted the importance of being able to reliably assess hazards in mountain environments and assume personal responsibility. The presented methods were judged suitable, though new suggestions emerged: additional types of hazards should be included, and target groups more clearly differentiated. While not all ideas could be implemented, several were incorporated directly into the project.

Impact and outlook

The project introduced innovative methods to address current and future challenges in alpine trail management. Its potential is already evident, as it effectively links different aspects of a complex system. It builds bridges between science and practice, between natural hazard management and recreational trail maintenance, and between climate-driven changes and the preservation of established structures. In doing so, it addresses both safety issues and the desire of many people to move freely in mountain landscapes.

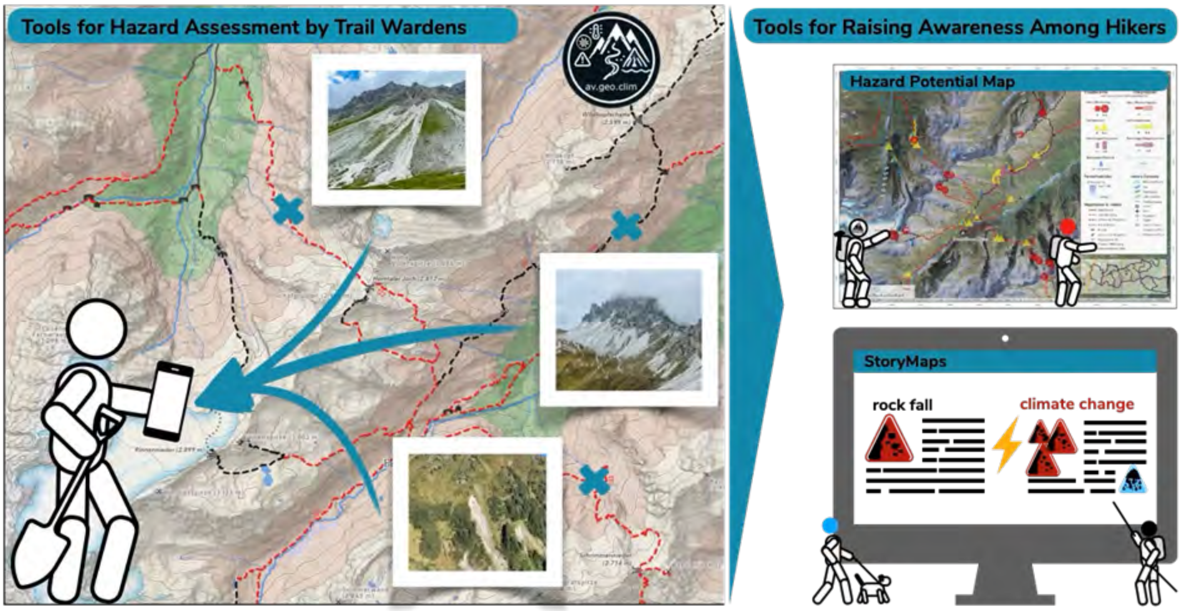

Fig. 8: *Abb. G-2: Core concept of the av.geo.clim project. Trail wardens collect data on hazardous locations along alpine hiking routes using a dedicated digital survey tool. The recorded data are processed by experts and communicated to specific target groups through hazard potential maps and interactive StoryMaps, aiming to raise awareness among hikers of natural hazards and the impact of climate change.*

StartClim2024.H: Comparison of the effects on soil water, yield and economics of two types of permanent montane grassland management

Grassland management plays an important role in disadvantaged mountainous regions of Austria, both for sustainable food production and for the preservation of cultural landscapes. Austrian agriculture is characterized by small-scale structures: according to the Green Report 2024, the average Austrian farm manages 44.9 hectares (as of 2020). Structural changes, such as the decline in the number of agricultural holdings, are clearly evident: according to the Green Report 2024, the number of agricultural and forestry holdings was 11% lower than in the previous full survey conducted in 2010. However, the decrease in the number of agricultural and forestry holdings contrasts with an increase in the average agricultural area and herd size per farm.

In permanent grassland, a distinction is made between intensive and extensive grassland. Extensive or semi-intensive permanent grassland areas are more commonly found in mountainous regions above 1,000 metres, where climatic and weather conditions often preclude other types of land use. In the Alps, the effects of climate change have become particularly evident in recent decades. In the humid climate of Austria's northern precipitation zones, a longer growing season and, with sufficient water supply, higher grassland yields can be expected. In those areas, the previously more extensive or semi-intensive grassland management could potentially shift to more intensive use (e.g., an additional cut).

Objective

Based on these expectations, the aim of this project was to compare two types of management of a permanent montane grassland area in a humid region so as to determine whether more intensive management could produce better yields than the current semi-intensive management. Additionally, the ecological (via biodiversity assessments) and economic impacts of an additional cut were evaluated using the FarmLife farm management tool.

The experimental site was located in western Upper Styria at an altitude of around 1,000 metres on an actively managed agricultural and forestry grassland farm. The test field was established in 2020 and equipped with a weather station, soil sensors and six lysimeters to collect seepage water.

Weather and soil moisture conditions

From 2021 to 2024, weather and soil moisture observations were conducted during the growing seasons (April to October). During these periods, total precipitation ranged from 764 mm to 858 mm, average air temperatures from 5.7°C to 7.5°C, and potential evapotranspiration from 415 mm to 430 mm. The climatic water balance indicated seepage water of between 223 mm and 377 mm. A decrease in frost and ice days and an increase in summer and tropical days were observed.

Potential evapotranspiration and soil water storage availability were slightly lower in the intensively managed area.

Dry matter yields

The dry matter yields ranged from 3,126 kg/ha to 7,683 kg/ha in the semi-intensively managed area and 4,687 kg/ha to 6,143 kg/ha in the intensively managed area. The differing yields suggest that this site may represent a borderline case between semi-intensive and intensive use. In periods with higher precipitation, more intensive management resulted in better yields, whereas in slightly drier periods, semi-intensive management produced higher yields. This indicates that a differentiated approach to grassland management could be promoted, allowing such areas to be used both in a site-appropriate (semi-intensive) manner and, potentially, more intensively. However, results from just four years of trials are not yet highly reliable, as weather patterns and the timing of snowmelt (and thus the start of the growing season) play a significant role in grassland yields.

Ecological observations and economic/ecological assessments

So far, ecological observations have shown no significant changes in either area. A longer period of observation would be needed to quantify ecological changes.

Economic evaluations, based on higher yields from more intensive management, showed no significant changes in income contribution compared to the lower-yielding semi-intensive management. The ecological assessment revealed that the greenhouse gas potential per hectare was lower for semi-intensive management than for more intensive management. Semi-intensive management, which is typical for the site, was evaluated as efficient and ecologically sustainable, while intensive management was assessed as extensive but still environmentally compatible.

Additional growing seasons will need to be analysed in the future to further consolidate the findings regarding the relationships between soil water, yield, ecology and economics,.

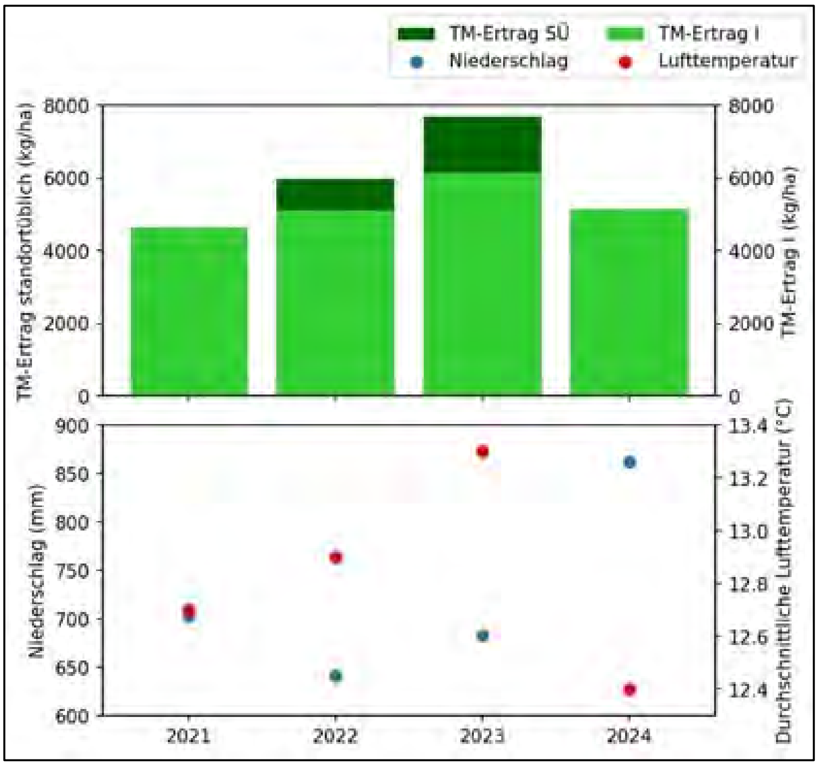

Fig. 9: *Dry matter yield (DM yield) of the two types of management on the test site suggest that it is a borderline region between half-intensive (SÜ) and intensive (I) utilization. Higher DM yields on both types of management were measured in vegetation periods with higher average air temperatures (2022 and 2023).*

Imprint

The complete final reports from StartClim2024 are available on the StartClim website. Please note that these are not currently available in an accessible format.

https://startclim.at/projektliste

If you have questions about the StartClim research programme visit http://www.startclim.at or contact us

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