FUTURE IMPERFECT

CLIMATE CHANGE AND ADAPTATION IN THE CARPATHIANS

CARPATHIAN CONVENTION
CARPATCLIM
Climate of the Carpathian Region
CarpathCC
CLIMATE CHANGE FRAMEWORK PROJECT
CARPIVIA
CARPATHIAN INTEGRATED ASSESSMENT OF VULNERABILITY TO CLIMATE CHANGE AND ECOSYSTEM-BASED ADAPTATION MEASURES
European Commission

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DISCLAIMER
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UNEP

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CLIMATE CHANGE AND ADAPTATION IN THE CARPATHIANS

Contents

Foreword

The Carpathian region, forming an integrative part of the wider Danube region, is a mountainous area of outstanding natural and cultural heritage shared by seven Carpathian countries, the majority of them being members of the European Union.

Like many other mountain regions in Europe and around the globe, the Carpathian mountain region provides a multitude of essential ecosystem goods and services such as water provision, food and agriculture products, forest products, tourism and energy provision that are important not only for local people, but also for downstream communities. But these ecosystem services – as well as the mountain communities that are their custodians and beneficiaries – are particularly vulnerable to the impacts of climate change.

Regional climate change projections suggest more irregular rainfall and a warmer climate in the Carpathian basin. According to recent findings, the Carpathian mountains will experience an increase of between 3.0˚C and 4.5˚C during this century. Precipitation patterns will also change, leading to profound consequences on the environment, on the economy and on human well-being. It is important to strengthen the sustainable use of natural resources in the mountain areas and adopt integrated, multi-sectoral ecosystem management approaches including climate change adaptation which will benefit not only mountain communities but also people downstream. Building on a sound scientific basis, a strategic approach to climate change adaptation across different sectors and levels of governance – in line with the EU Strategy on adaptation to climate change, adopted by the European Commission in April 2013 – is necessary.

Following an initiative by the European Parliament and funded by the European Union, important research by several teams of experts has been undertaken in recent years in order to further investigate climate change and adaptation in the Carpathians: from climate change projections to in-depth assessments of the vulnerability to climate change of ecosystems and their services in the Carpathian region. This has led to the establishment of a diversified portfolio of sustainable adaptation measures with the active and valuable cooperation of international environmental experts. At the intergovernmental level - facilitated by the Interim Secretariat in Vienna - Parties to the Carpathian Convention have succeeded in developing the "Strategic Agenda on adaptation to climate change in the Carpathian Region". This will be adopted by Ministers at the Fourth Meeting of the Conference of the Parties to the Carpathian Convention (COP4), in Mikulov, Czech Republic, from 23 to 26 September 2014 and will provide the framework for further strategic action.

This report presents the major findings and outcomes of the three EU projects – CARPIVIA, CarpathCC and CARPATCLIM – funded under the preparatory action "Climate of the Carpathian Basin" approved by the European Parliament. Results from these projects are being integrated to the European Climate Adaptation Platform (Climate-ADAPT). With this report we hope to further raise awareness about the Carpathian region – a unique region in the heart of Europe which faces the challenge of the impacts of climate change. We also hope to stimulate further debate on climate change and adaptation in the Carpathians leading to concrete follow-up actions that may also serve as inspiration for other mountain regions in Europe and beyond.

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Minister of Environment of the Slovak Republic
(Presidency of Carpathian Convention 2011–2014)

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European Commissioner for the Environment

The Carpathian Region

Figure 1: *The Carpathian region covers territory in seven countries. (GRID-Arendal)*

Executive summary

This synthesis report is directed at policy makers and the public in the Carpathian region. It brings together important findings and recommendations about climate change impacts and adaptation from three linked research studies funded by the European Commission:

- Climate of the Carpathian Region (CARPATCLIM), led by the Hungarian Meteorological Service, harmonized historic climate data from 1961–2010. Its main aim was to improve climate data to investigate how the regional climate has changed over this period. It produced a high-resolution database for the Larger Carpathian Region, freely available at www.carpatclim-eu.org.

- Carpathian Integrated Assessment of Vulnerability to Climate Change and Ecosystem-based Adaptation Measures (CARPIVIA) assessed the vulnerability to climate change of the Carpathian region's main ecosystems. The project produced an inventory of climate change effects and ecosystem-based adaptation measures. For further information see www.carpivia.eu.

- Climate change in the Carpathian Region (CarpathCC) examined the vulnerability of water, soil, forests, ecosystems and related production systems. It proposed concrete ecosystem-based adaptation measures, and it assessed their costs and benefits. For further information see www.carpathcc.eu.

Together these studies raise awareness about the extent and impacts of climate change in six important sectors in the Carpathian region: water resources, forests, wetlands, grasslands, agriculture and tourism. They also support an informed and rapid response by decision-makers in the region in order to reduce the effects of climate change.

The studies show that temperature and precipitation are changing throughout the Carpathians.

Increasing winter and summer temperatures threaten local and national policy objectives for agriculture, winter tourism, and rural development, and raise a host of economic and social issues. The average annual temperature has increased by 0.6ºC to 1.6ºC, particularly in the summer when the increase is expected to be at least 1.0ºC but could reach 2.4ºC. In the last 50 years, the strongest increase has been observed in the western and eastern part of the Carpathians and in the lower regions. Higher elevations have seen less temperature change. Projections estimate that the average temperature will increase by between 3ºC and 4.5ºC by the end of this century.

Precipitation changes show even higher spatial variability. Annual precipitation has increased in most of the Carpathian region in the last 50 years with the exception of the western and south-eastern areas where there has been a decrease. In contrast, the north-east part of the region has seen an increase in precipitation of 300–400 mm in the last 50 years. Looking towards the future, precipitation is expected to increase but with higher uncertainty. However, the wide range of estimates means that any statements about the future should be based on both observed changes from the past and model projections.

Adaptation in Six Vulnerable Sectors

Water resources

Reduced snow cover, sudden and heavy rainfalls, and changes in precipitation patterns will increase the risk of floods. More precipitation over a short period of time will increase erosion and landslide risks. In some regions, river water levels will decline and this will cause an increase in drought events. Declining groundwater levels may affect the availability and quality of drinking water for communities that rely on mountain streams.

Adaptation measures will need to be included as an integral part of river basin management plans in the Carpathians in order to be effective. Such measures include:

- Adjusting permits for water use or pollution discharge;
- Introducing smart irrigation systems;
- Planting forests and combating illegal logging in catchment areas in order to reduce nutrient loading and soil erosion;
- Restoring floodplains near rivers and streams to buffer extreme runoff and reduce flows of nutrients; and
- Ensuring legal frameworks are in place to support planning and implementation of adaptation measures.

Forests and Forestry

The way climate change affects forests and forestry depends on many factors, such as forest structure and species composition, applied management practises, natural conditions and also the effect of stressors such as air pollution, which can amplify forest vulnerability to climate change. At lower elevations, mainly in south Slovakia, Romania, Hungary and Serbia, forests are particularly vulnerable to drought, which can also trigger pest outbreaks. In these regions, drought-induced forest decline has occurred and can be expected to increase in the future, affecting adversely wood production, biodiversity and other ecosystem services.

More intense droughts and windstorms are followed by outbreaks of bark beetles and defoliating insects. New pest species are moving in, such as the Northern spruce bark beetle, which has recently been mainly affecting spruce forests in Romania. At the same time, capacity of regional economies to implement efficient adaptive measures is weak across the Carpathians.

Adaptation measures include :

- Promoting sustainable forest management that utilizes the concepts of close-to-nature and multi-functional forestry;
- Encouraging adaptive forest management, including the modification of tree species composition and proper use of forest genetic resources;
- Supporting and harmonizing regional and European forest monitoring schemes, including those tracking newly emerging pests and pathogens; and
- Increasing awareness about the indispensable role of forests in integrated watershed management, particularly in biodiversity maintenance, water regulation and erosion control.

Wetlands

High altitude wetlands are crucial for both flood management and biodiversity. They act as sponges that reduce flood peaks in winter and low flows in summer. Increased temperatures threaten to dry out wetlands and increase the length and severity of droughts. Wetland loss reduces habitats for many dependent plant and animal species and leads to habitat fragmentation that could threaten migratory birds and amphibians at the regional level. The most vulnerable wetland habitats are peatlands, due to their limited resilience to climate variability and their sensitivity to human activities and changes in land use.

Adaptation measures include:

- Developing monitoring systems for aquatic ecosystems in the region;
- Integrating wetland protection with flood control practices;
- Supporting programmes aimed at wetland and peatland restoration, floodplain rehabilitation; and
- Creating new wetlands and lakes to enhance local water retention capacity and support biodiversity.

Grasslands

Carpathian grasslands are among the richest grasslands in Europe. Their high biodiversity value is a direct result of hundreds of years of traditional management and animal husbandry. An increase in temperature, the occurrence of more extreme droughts and floods, soil erosion, and the tree line shifting upward, as well as agricultural intensification, are all expected to reduce grassland quality and coverage, leading to habitat fragmentation and species loss. Long-established and stable grassland communities (e.g. mountain hay-making meadows) are more tolerant to climate change than newer grasslands. Maintaining these traditional management methods is vital. Grazing, rotation, mowing, mulching and fertilization are the five main management measures that are the most widely applied within the Carpathians. Grazing and mowing were found to be of high importance and should be maintained in the future. In contrast, land rotation will be less suitable in the future for grassland management due to forest encroachment. Mulching and the use of fertilizers in order to increase the nutrient input are expected to increase the presence of invasive species and affect water quality, and thus are not suitable for grassland management. Finally, agro-environmental programmes can offer indispensable support for maintaining connectivity and extensive grassland management.

Adaptation measures include:
- Implementing agro-environment measures and the EU nature & biodiversity Natura2000 management plans;
- Diversifying species and breeds of crops and animals; and
- Managing through (extensive) grazing and mowing, avoiding the abandonment of land or mulching or fertilizing techniques, and avoiding overgrazing.

Agriculture

Agriculture will experience significant pressures from changes in precipitation, temperature and fluctuating seasons. While agriculture may become feasible at higher altitudes in some parts of the Carpathian region, overall maize and wheat yields will decline. Elsewhere, sunflower and soya yields might increase due to higher temperatures and migration of the northern limit of these crops. Likewise, winter wheat production is expected to increase. In general a shift towards planting winter crops during spring will be possible. Vulnerability to pests is predicted to rise, accompanied by productivity losses as a result of soil erosion, groundwater depletion, and extreme weather events. Preliminary results show that small-scale farmers in remote villages in Romania and Serbia could be among the most vulnerable. Traditional mixed agro-ecosystems in the Carpathians may disappear through a combination of land abandonment, land use change and increased expansion of forest area propelled by climate change.

Adaptation measures include:
- Supporting small-scale traditional farms as important economic activities delivering multiple ecosystem services; and
- Supporting agro-environment programmes that are critical to maintaining and enhancing biodiversity and viability of semi- natural grasslands and mixed agro-ecosystems.

Tourism

Tourism will experience both positive and negative effects from climate change. Ecotourism, summer, health, and vocational tourism may be positively influenced by climate change. Rising temperatures in summer both in the Carpathians and elsewhere, such as the Mediterranean region, may bring additional tourists to the mountains seeking more comfortable temperatures. On the other hand, over the next 50 years the possibilities of winter sports may become more limited because of a projected decline in snow depth and duration. However, tourism in the Carpathians is diversified and only a small number of annual visits depend on snow availability. Thus changes in snow extent and depth will not affect tourism turnover as much as was formerly supposed. Besides, the profile of the old, winter sport-based resorts is changing and the majority of tourists now visit in the summer, meaning that tourism in higher mountains is already adapting to new conditions.

The main adaptation measure the study recommends is to continue diversifying resorts and markets. In addition, it advises evaluating investments in tourism infrastructure in the light of projected snow and water availability.

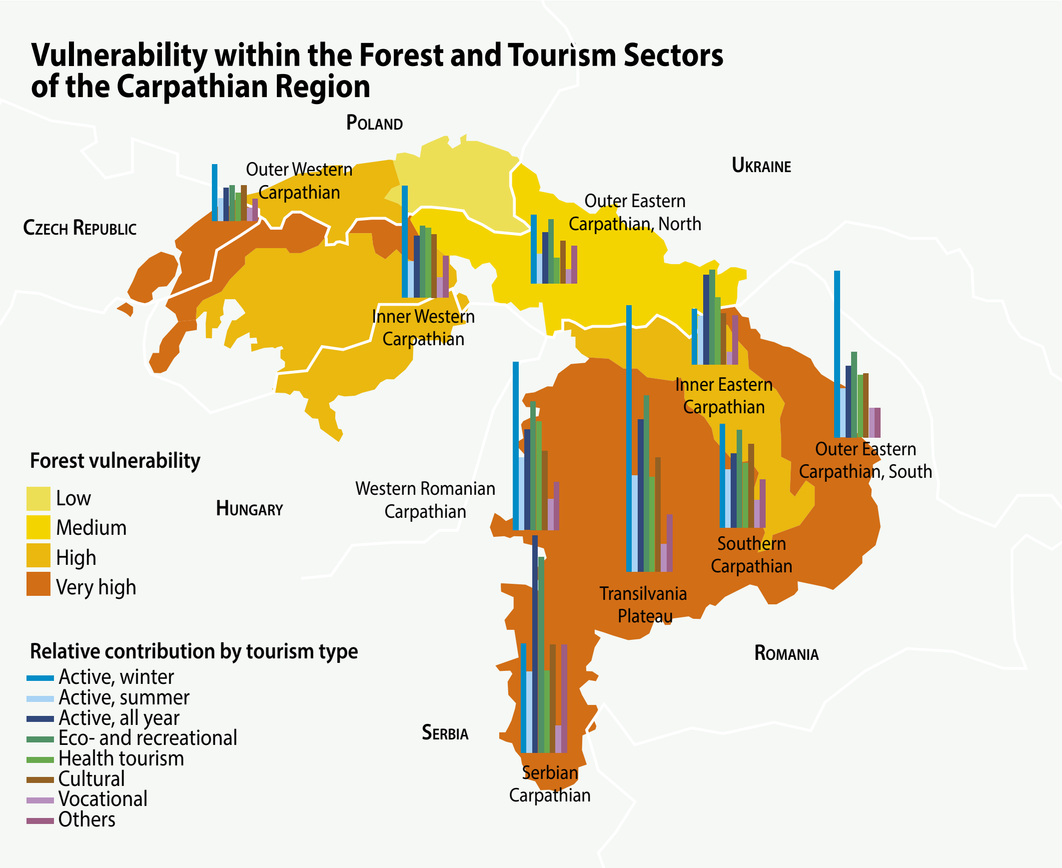

Figure 2: *Vulnerability to climate change varies across the Carpathian region in different sectors. (Map by GRID-Arendal; source: CarpathCC)*

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Towards a Strategic Agenda on Adaptation to Climate Change in the Carpathian region

Linking different policies of nature conservation, river basin management, and sustainable farming could significantly strengthen the Carpathian region and its resilience to climate change. Regional cooperation agreements, like the Carpathian Convention, can be a critical vehicle to mainstream resilience in different countries. The added value of increased transnational cooperation and joint activities is especially important when planning for climate change adaptation, since many of the predicted impacts of climate change, such as seasonal changes in temperature and precipitation, will occur over vast geographical areas, affecting several countries at once. Many of the possible measures are best planned scaled to the eco-region rather than the nation-state. Further, many of the tools and capacities required for climate change adaptation are currently lacking, such as the ability to designate and map future refuge habitats for wetlands and grasslands. This may need to be developed at the transnational level, with the support of externally funded joint initiatives that could fill the gaps and build cooperative capacity. Financial resources are limited. A key action is to create flexible and equitable financial instruments that facilitate benefit and burden sharing, and support a diverse set of potentially better-adapted new activities rather than to compensate for climate impacts on existing activities. To succeed, it will be essential to build new partnerships between governments, civil society, the research and education institutions, the private sector and international organisations.

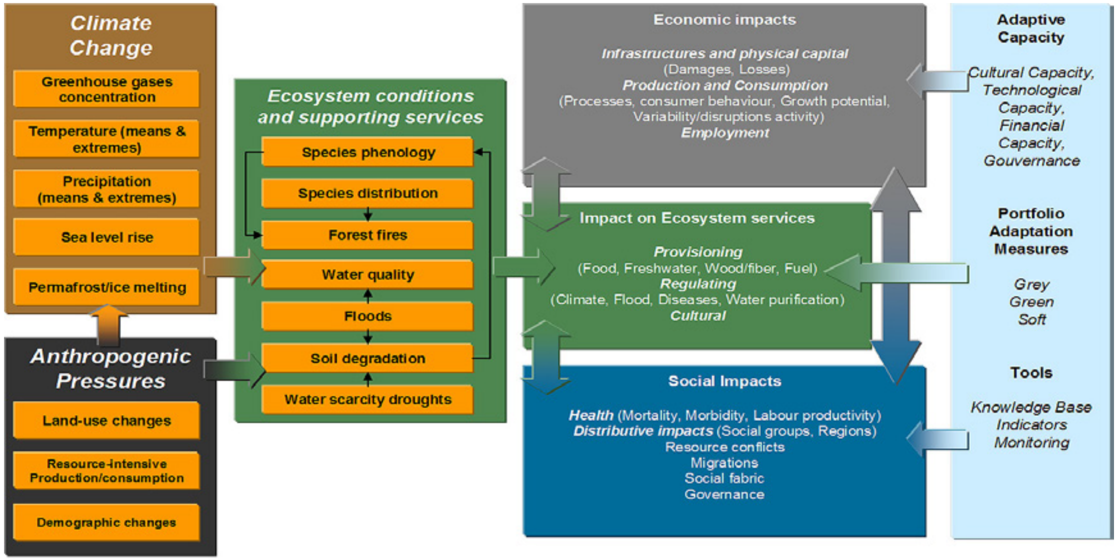

Figure 3: *Adapting to Climate Change: Ecosystem pathway of vulnerability and adaptation. This figure describes the analytical framework for the assessment of vulnerability to climate change and definition of adaptation strategies. It highlights the central role of ecosystems and ecosystem services in the transmission of impacts to the economy and society. It also shows the importance of healthy ecosystem for a cost-effective adaptation strategy (source: J. Delsalle, European Commission, 2014).*

The Carpathian Region

Geography

The Carpathian region covers an area of about 210,000 square kilometres. It is the second most extensive mountain system in Europe besides the Alps. The Carpathians are one of the most biologically outstanding ecosystems in the world. The region hosts unique natural treasures of great beauty and ecological value and the headwaters of several major rivers.

The Carpathian region is shared by seven Central and Eastern European countries,[1] five of which are members of the European Union.

The Carpathians include Eastern Europe's largest contiguous forest ecosystem, which provides habitat and refuge for many endangered species. The mountains are a hotspot of biodiversity, including Europe's largest remaining areas of virgin and old growth forest outside of Russia. A bridge between Europe's northern and southwestern forests, the range serves as a corridor for the dispersal of plants and animals throughout Europe.


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The native flora of the Carpathians is among the richest on the European continent. It is composed of almost 4,000 species and subspecies belonging to 131 families and 710 genera, making up approximately 30% of the 12,500 European flora.

These mountains contain Europe's largest populations of brown bears, wolves, lynx, European bison and rare bird species including the globally threatened Imperial Eagle. Some 45% of the continent's wolves — a species extirpated in many Western and Central European countries — can be found here.

The Carpathians are also a major source of freshwater. Part of three river basins cover most of the Carpathian region: the basins of Danube, Dniester and Vistula Generally, river valleys in the region have a small retention capacity, causing a sudden rise of water levels in rivers during heavy rainfall.

In addition to fostering great biodiversity, the wider Carpathian region, including forelands, is home to millions of people. They live in environments ranging from small communities located in remote mountain areas to urban centers, such as Ko šice and Cluj-Napoca. Figures 1 and 4 shows the extent of the Carpathian Mountain region.

1. Czech Republic, Hungary, Republic of Poland, Romania, Republic of Serbia, Slovak Republic and Ukraine.

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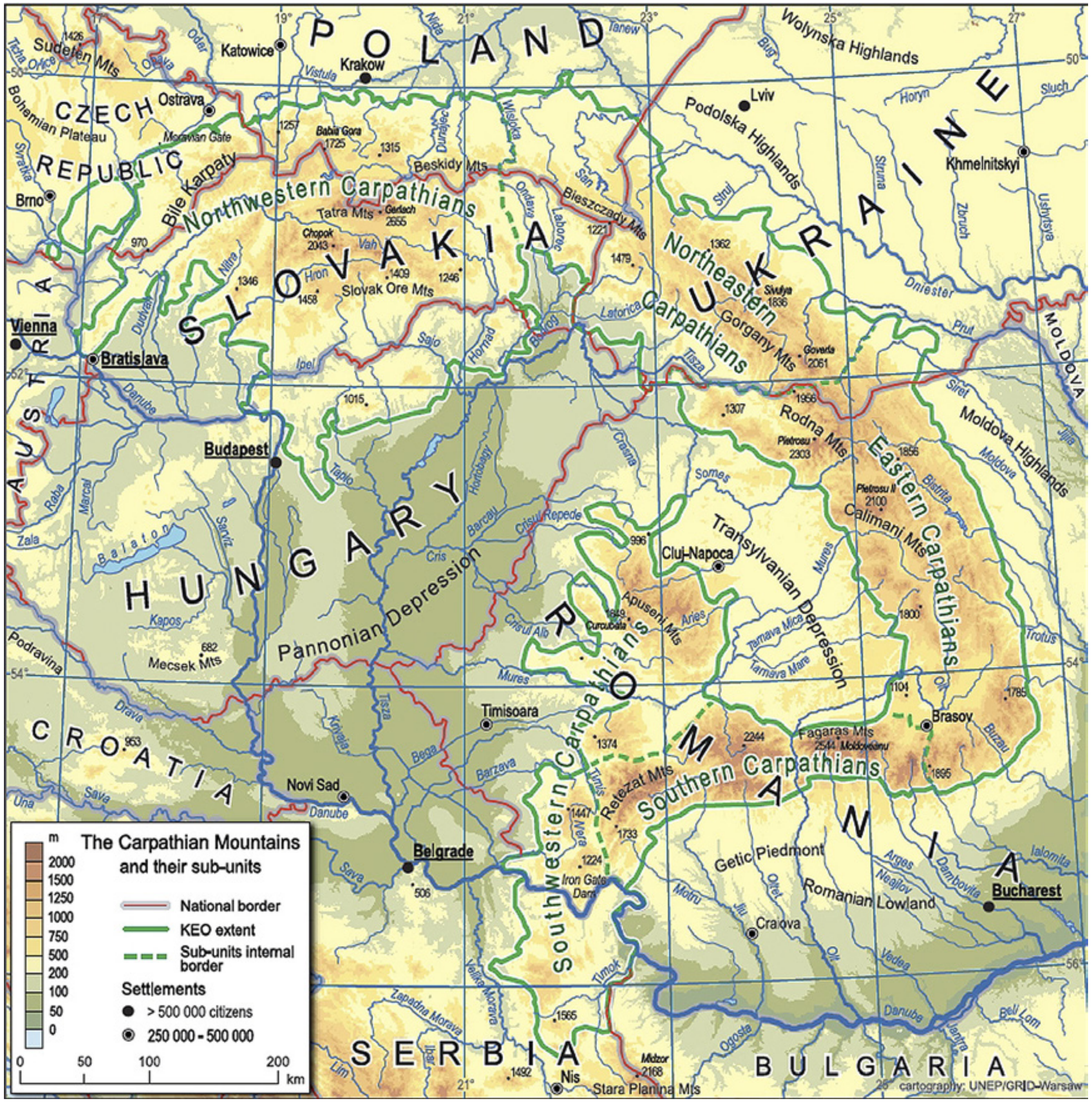

Figure 4: *The Carpathian Region (source: Carpathians Environment Outlook 2007; UNEP/GRIDGeneva).*

The Carpathian Convention: Cooperation and Sustainable Development

The Carpathians form a living environment for unique wildlife and human culture in the heart of Europe. But the region is also threatened by a variety of natural and human impacts, such as land abandonment, habitat conversion and fragmentation, deforestation, exploitation of natural resources, pollution and climate change.

To effectively counteract these threats, as well as to preserve extraordinary natural and cultural heritage, Carpathian countries and interested organizations joined together to establish an international legal framework promoting the sustainable development of the region, which was inspired by the Alpine Convention. The “Carpathian Convention process” started in 2001, when the Government of Ukraine asked the United Nations Environment Programme (UNEP) to facilitate an intergovernmental consultation process among the Carpathian countries with the aim of drafting an international convention on the Carpathian Mountains. The Framework Convention on the Protection and Sustainable Development of the Carpathians (Carpathian Convention) was adopted and signed by the seven countries sharing the Carpathians in May 2003 in Kyiv, Ukraine, and entered into force in January 2006.

UNEP was requested to continue supporting the Convention process and provide support to the Interim Secretariat of the Carpathian Convention (ISCC) established in May 2004, which is located in the UNEP Vienna Office. The Convention provides a transnational cooperation platform for the sustainable development of the Carpathian region. In order to bring the Convention to life, its bodies develop activities in several thematic areas from the development of new protocols and the establishment of strategic partnerships with key actors in the region, to the realization of different initiatives within the Carpathians and beyond. The Convention is also a forum for dialogue between all the stakeholders acting in the Carpathian area including local communities, NGOs, regional and national authorities and international organizations

Transnational cooperation networks have been established as well, such as the Carpathian Network of Protected Areas (CNPA) which was established in cooperation with a similar Alpine initiative, Alparc. Strategic projects are developed and implemented, such as BioREGIO Carpathians, a project on integrated management of biological and landscape diversity for sustainable regional development and ecological connectivity in the Carpathians. Other projects include Access2Mountain, which aims to improve sustainable access and connection to, between, and within sensitive mountain regions.

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The Changing Carpathian Climate

The Atlantic Ocean, the Mediterranean and the landmass of Asia all influence the climate of the Carpathian Mountains. For that reason, the regional climate shows high natural variability, which makes climate change detection more difficult.

The seven Carpathian countries have different meteorological networks, data management methods and policies. In order to better compile, coordinate and share this information, a project on the climate of the Carpathian region was launched supported by the European Parliament and supervised by the Joint Research Centre of the European Commission (Ispra, Italy). The main aim of this project was to establish a freely available, high-resolution, gridded climatological database. The database contains daily data for more than 50 meteorological parameters and uses a 10x10 kilometre spatial resolution for the period 1961-2010. This resolution is important for understanding the regional effects of climate change. Participants, mainly from national hydro-meteorological services, have been working in parallel using the same data management and gridding methods and software. Near the borders, bilateral data exchange assured the consistency of the database. Data and detailed description of how the database was developed are available at www.carpatclim-eu.org.

Figure 5 shows results from the project for mean annual temperatures and annual precipitation levels for two periods. The warming trend is clear even within this short period of time, although the main pattern of annual precipitation shows only local differences. The warming trend is seen for 1961-2010, especially in the western part of the region, where the warming is between 1.1°C - 2.0°C.

Figure 6 shows the seasonal temperature changes from 1961 to 2010. Most warming – between 1.0° and 2.4°C – is seen in summer. This warming leads to

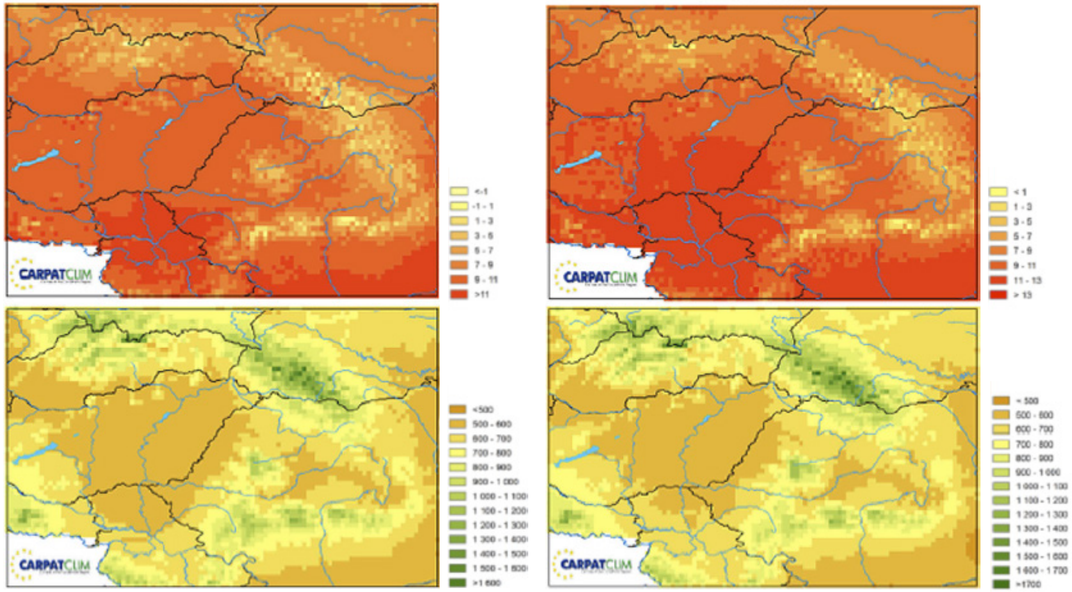

Figure 5: *Mean annual temperature (upper row) and annual precipitation (lower row) for the period 1961–1990 (left) and 1981–2010 (right) (source: CARPATCLIM).*

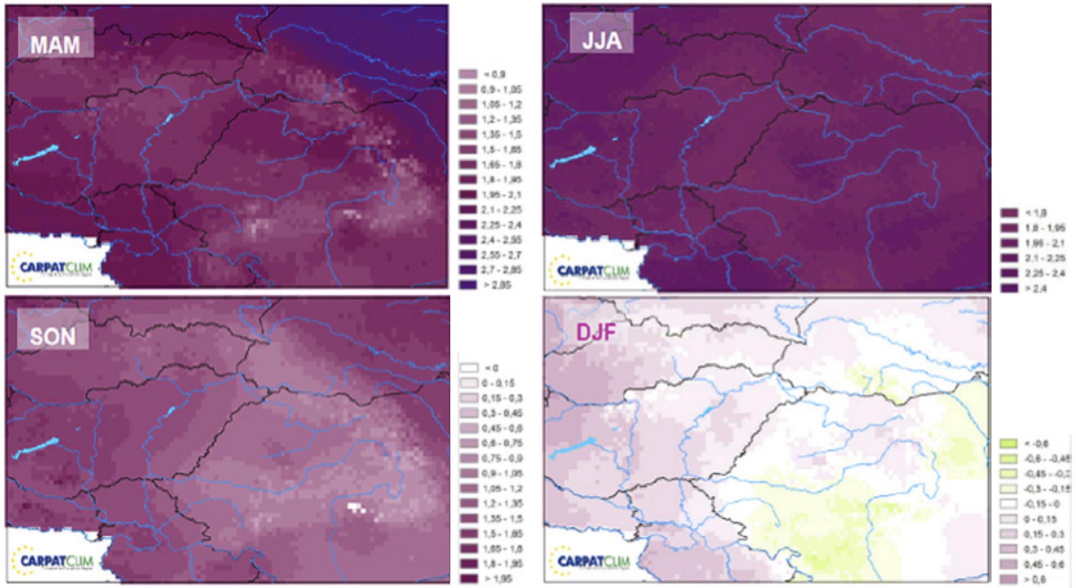

Figure 6: *Seasonal temperature changes, 1961–2010 (spring upper left, summer upper right, autumn lower left, winter lower right) (source: CARPATCLIM).*

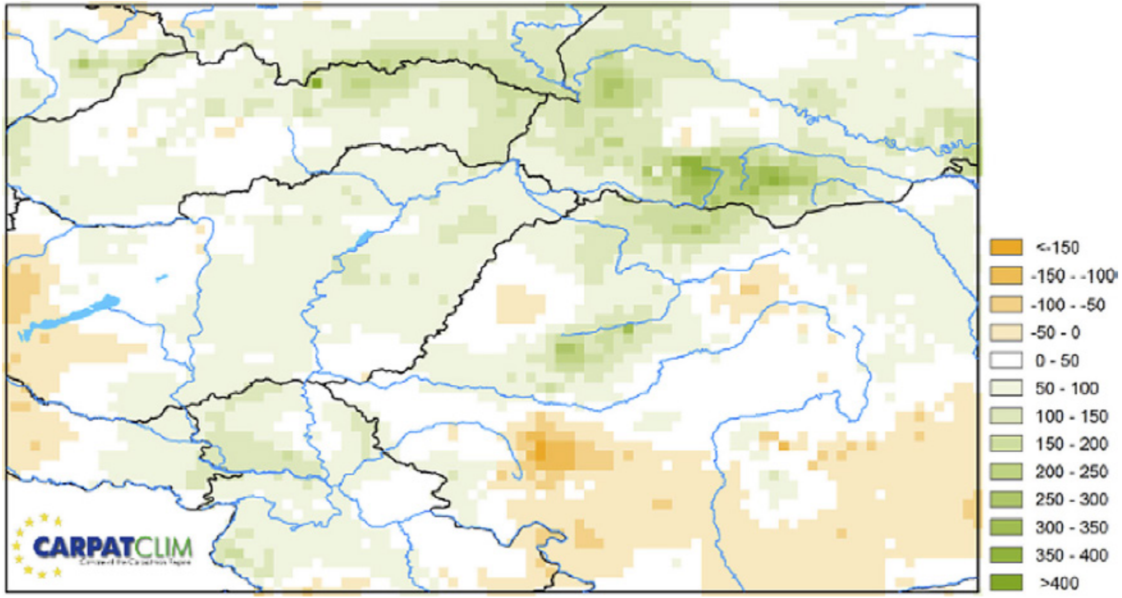

Figure 7: *Change in annual precipitation 1961–2010 (source: CARPATCLIM).*

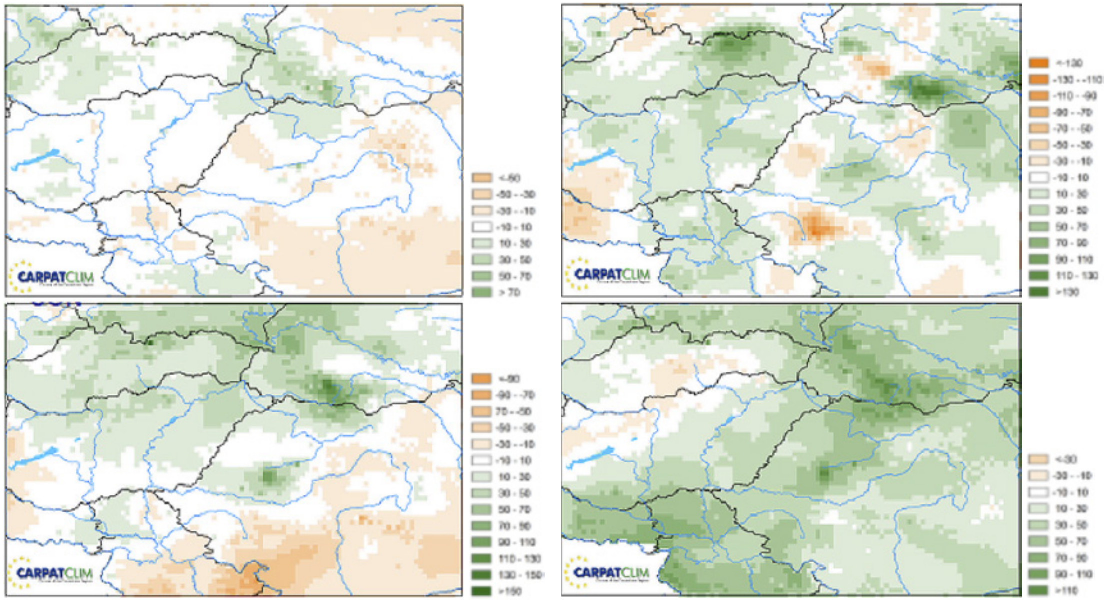

Figure 8: *Change in seasonal precipitation 1961–2010 (spring upper left, summer upper right, autumn lower left, winter lower right) (source: CARPATCLIM).*

an important increase of the frequency and intensity of heat waves. Warming was less pronounced during the winter, when temperature increase was less than 0.4 °C everywhere. Some areas even show a slight cooling during the CARPATCLIM investigation period.

Compared to temperature, changes in precipitation resemble a more mosaic pattern. Total annual precipitation has large spatial variability. The main spatial distribution shows decreasing precipitation in the western and south-eastern parts of the region

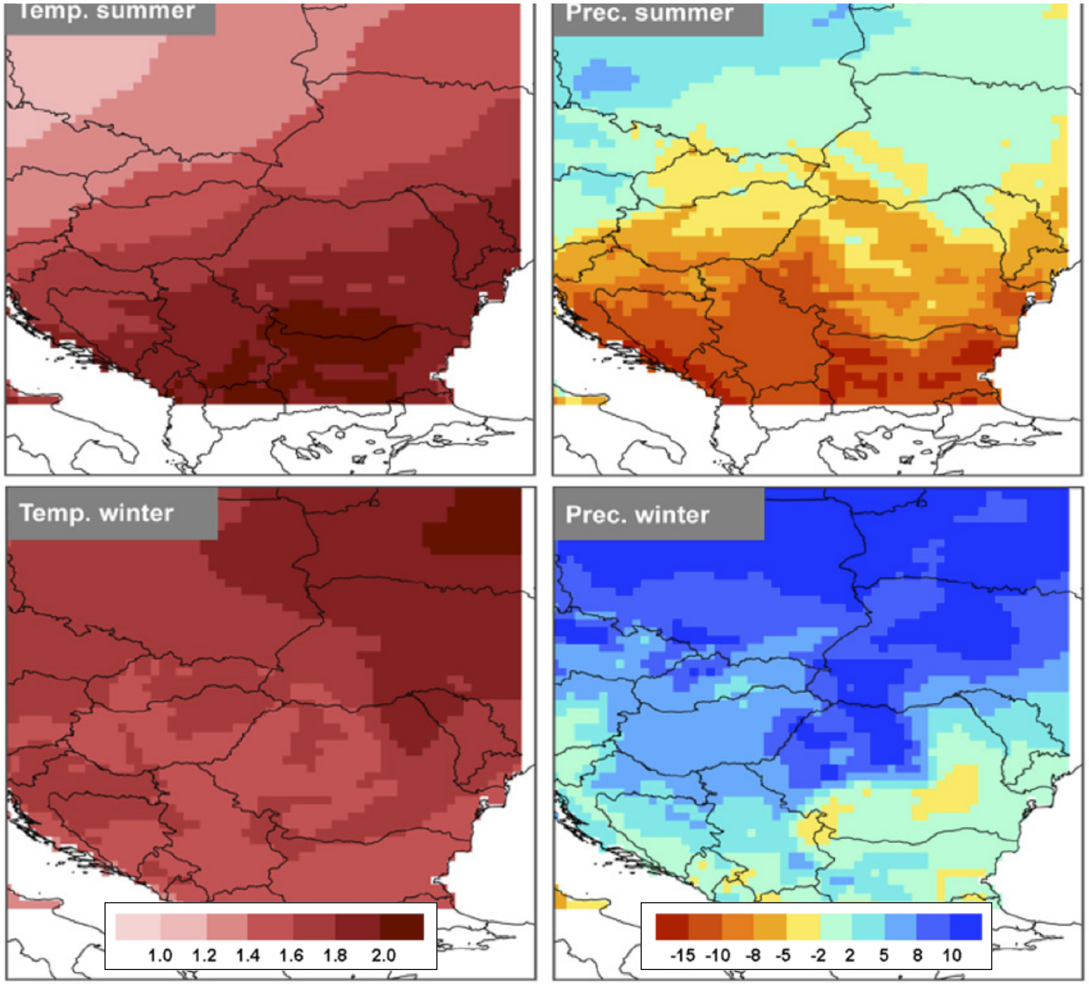

Figure 9: *Changes in daily mean air temperature (°C) (left) and precipitation (%) (right) in the greater Carpathian region in winter (DJF) and summer (JJA) as the multi-model mean for the years 2021–2050 relative to 1971–2000 (absolute differences in mm), for the A1B greenhouse gas emissions scenario with 14 different GCM-RCM combinations from the ENSEMBLES project (source: CARPATCLIM).*

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but with an increase in the north, especially in the north-east (Figure 7).

The seasonal trends show even larger spatial differences (Figure 8). We can detect wetter and dryer areas in each season, but overall increasing precipitation is found in winter and summer, while a decrease happens in spring.

While climate models suggest a north-south gradient in the region, observations support a west-east gradient for the precipitation trends, caused mainly by drying in the western part of the region. Comparing the observational and modelled trends, clear differences can be detected especially in summer (Figures 8 and 9). Model results show less spatial variability and present more unified patterns than the measurements. There are also temporal differences, especially in summer. Models show summer drying that is not supported by observations. The investigated time interval is not the same, but they are quite close to each other (1961-2010 and 2016-35 relative to 1985-2005), which leads to the conclusion that differences cannot be explained by the different time periods.

According to the reports of the Intergovernmental Panel on Climate Change (IPCC), more intense periods of precipitation can be expected. Despite the decreasing amount of precipitation, heavy rainfalls can happen more frequently, and they can be more intense. While the maps of precipitation totals and tendencies show large spatial variability, the intensification of precipitation is quite consistent. Intensification can be described by several indices and parameters. Increasing intensity and decreasing number of wet days lead to more runoff and less infiltration. This worsens the surface water balance, reducing water safety and increasing erosion. All these effects require water management adaptation measures.

With respect to more extreme events, the number of hot days is increasing, whereas extreme cold temperature values are decreasing. Figure 10 shows

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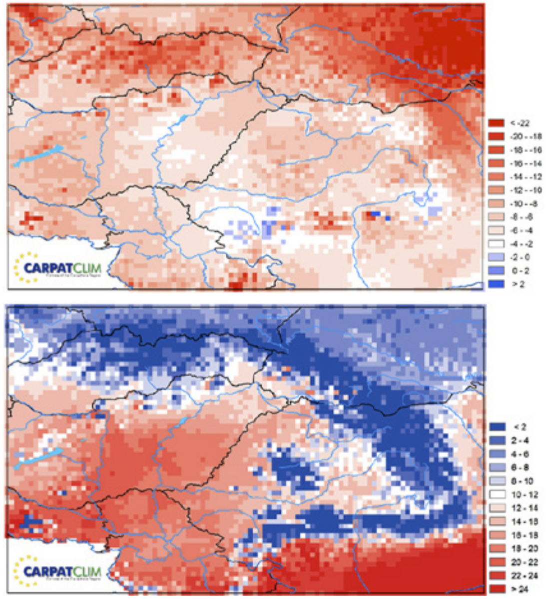

Figure 10: *Change in the number of winter days per year (daily maximum < 0°C, up) and hot days per year (daily maximum ≥ 30°C, down) in the Carpathian region in the period of 1961–2010 (source: CARPATCLIM).*

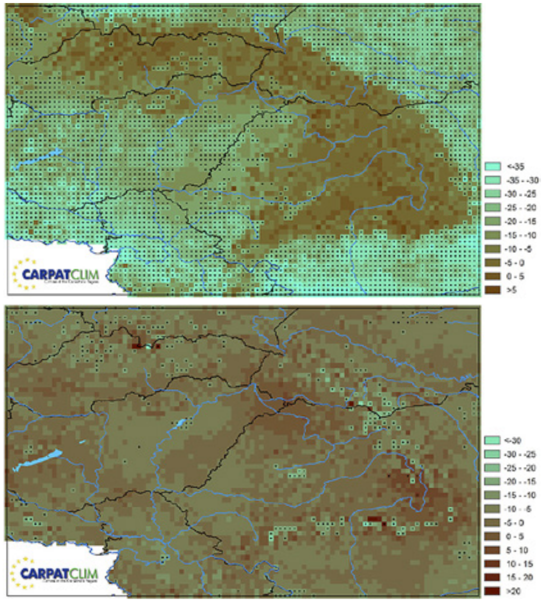

Figure 11: *Change in the start date of the growing season 5°C (up) and 10°C (down) in days in the period of 1961–2010. Significant changes at 90% level are marked with dots (source: CARPATCLIM).*

that the number of winter days decreases everywhere in the Carpathian region with very few exceptions. The greatest decline can be seen in the northwest Carpathians (a reduction of 18 to 20 days between 1961 and 2010). In the south and east Carpathians, a small increase appears. The change in the number of hot days correlates strongly with topography – fewer hot days are seen at higher levels in the mountains than at lower altitudes. The increase of hot days is higher in river basins, especially in the territory between the Danube and Tisza rivers (18 –22). The Transylvanian basin shows slower increase in hot days. The South and East Carpathians showed the largest growth in the number of hot days (over 24 between 1961 and 2010).

These changes are already having an effect on the environment, economy and human health. For example, the vegetation growing period starts earlier (Figure 11). The changes are larger and more significant at the basic temperature 5°C, than at 10°C. Vegetation growth has been starting about 15-20 days earlier in the first decade of the 21st Century, than in the middle of the 20th Century.

In summary, increasing temperatures are expected throughout the Carpathians. In summer the highest increase is projected in the South-eastern part and lowest in the North-western part of the region. Model studies largely agree in projecting an increase of winter precipitation and a decrease of summer precipitation. Although the mean annual values of precipitation will remain almost constant (with a small annual increase in the Northwest and decrease for the rest of the region that is strongest in the Southern part of the Carpathians), decreases in summer precipitation are projected of above 20 % and winter precipitation is projected to increase in most areas with 5 to 15 %.

The large and opposite trends for different seasons imply that the annual distribution of precipitation can be restructured. The summer season may become the driest, and the winter is expected to be the wettest season by the end of the 21st century.

Vulnerability and Adaption in Six Important Sectors

The CARPIVIA, CarpathCC and CARPATCLIM projects assessed the vulnerability of the Carpathian region to climate change in combination with other anthropogenic pressures. Vulnerability was assessed for the major ecosystems and economic sectors that depend on them. First, possible climate change scenarios were identified and impacts were assessed. Next, vulnerability was described as a function of the impacts. Adaptation options were then considered.

As an illustration of this approach, Figure 12 shows the results from the qualitative analysis on ecosystem services provided by selected grasslands habitats. Services with a high score are considered highly significant or important for providing benefits. The qualitative assessment is based on expert judgment, a literature review and information gained from stakeholders during a workshop in 2013. This type of analysis can be useful to assess the impacts of adaptation measures on ecosystem services affected by future climate change. It forms a basis for further quantification and assigning a monetary value to ecosystem services.

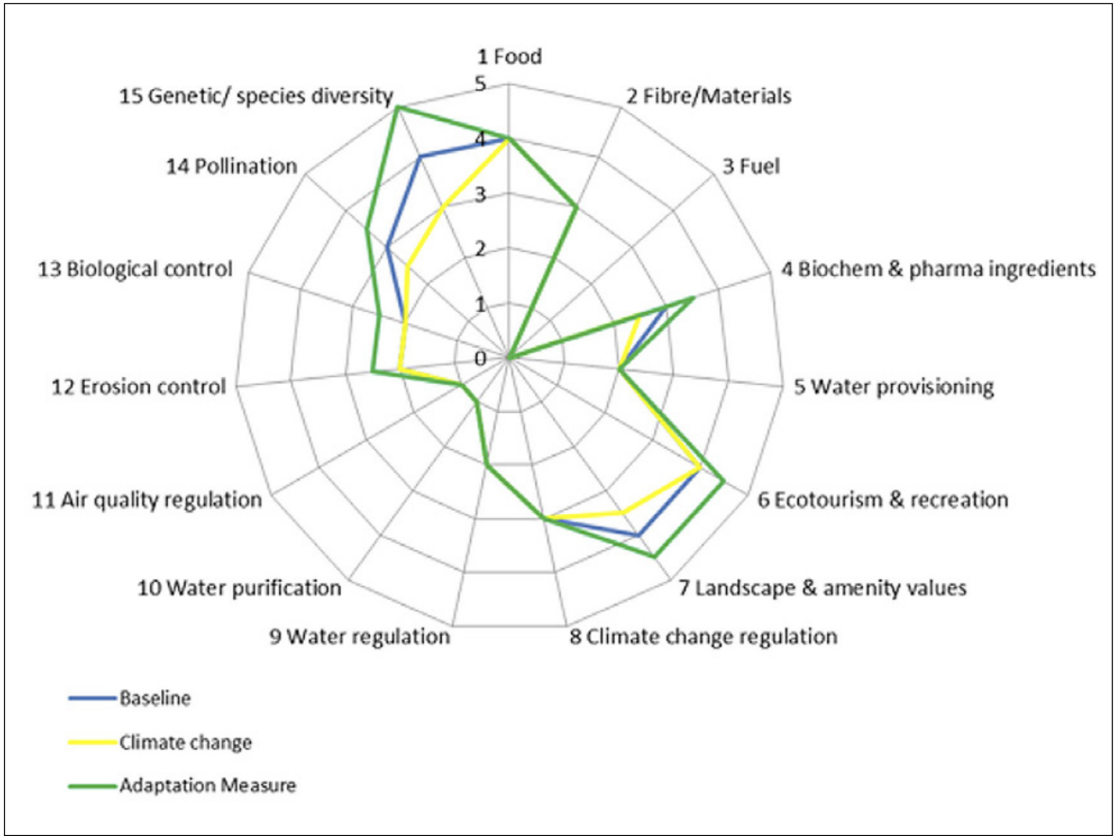

Figure 12: *An illustration of the significance of ecosystem services by sector (5 = very high). This example is for grasslands (source: CarpathCC).*

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Water resources

According to model-based projections, the discharge of Carpathian rivers is expected to increase during the winter and decrease during the summer as a result of climate change (Figure 14).

Decreasing summer flows will have negative impacts on ecosystems and ecosystem services. Periods when ecological water demands will not be met will increase, leading to irreversible damage to aquatic and riparian ecosystems. Settlements, agriculture and industry will likely suffer from more water shortages. At the same time, increasing wintertime flows will likely exacerbate existing flood problems.

One of the most efficient adaptation measures against the combined threat of droughts and floods is water storage. In the first place, adaptation of the management of existing structures has to be taken into consideration. Model-based investigations proved that low-flow levels from a reservoir on the Mures River Basin could be improved by 20% merely by modifying its management.

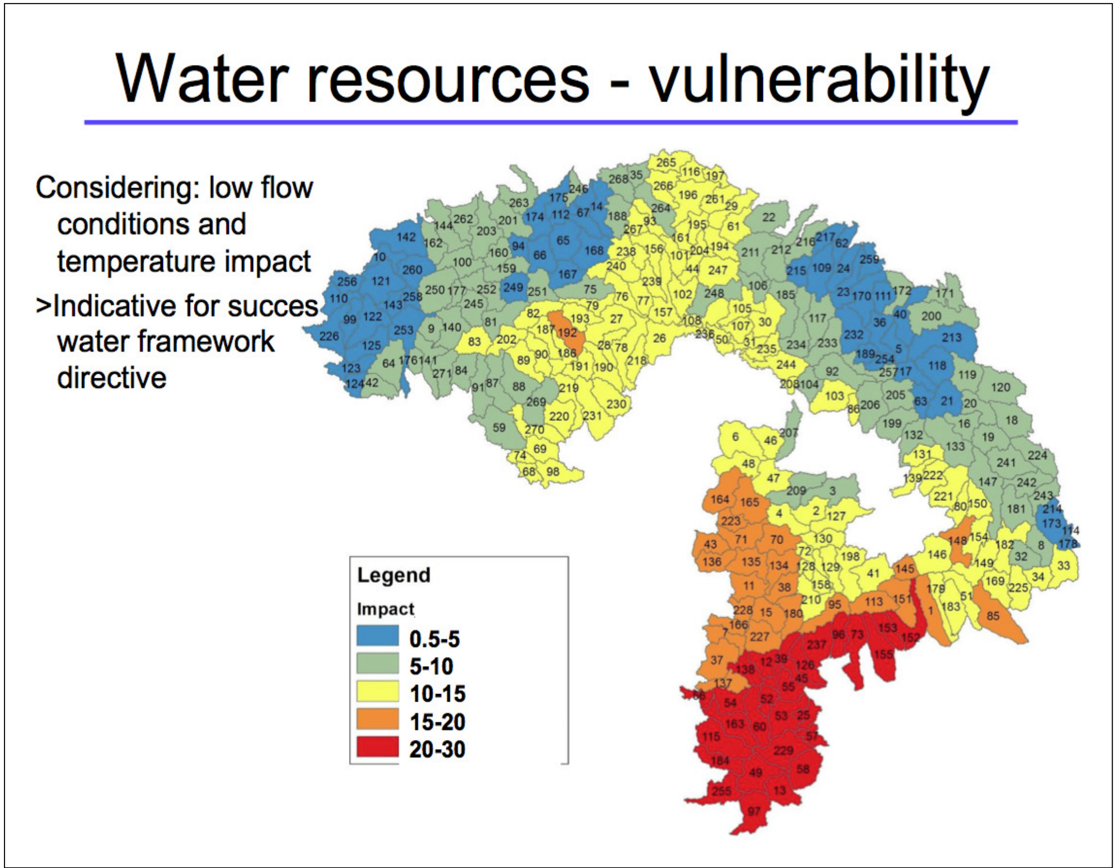

Figure 13: *Vulnerability of water resources in the Carpathians (source: CarpathCC).*

If this is not sufficient, then storage capacities can be improved. Structural measures such as constructing dams[2] water tanks and subsurface reservoirs are recommended. Another promising structural measure is the installation of rainwater harvesting systems on slopes. Besides flood and low-flow control, terraces, embankments, and other structures have additional, local advantages. They reduce surface erosion, counteract the desiccation of forests and cool the air thanks to the increased rate of evapotranspiration.

Sub-surface water storage can also be enhanced by protecting and restoring open grasslands so more rainwater can infiltrate into the deeper soil layers than in forested areas. This land use measure is especially recommended for the karstic systems in the Carpathians, where grasslands are the primary sources of water supply for the sub-surface water resources.

Land storage capacities can also be increased by eliminating road networks, especially in the Eastern Carpathians. Intensively used dirt roads act as drains accelerating runoff and causing local erosion problems. Eliminating roads necessitates the adjustment of land use. For this purpose activities requiring frequent transportation (e.g. hay production) have to be replaced by transportation-free uses, such as grazing or nature conservation.

2. Dam construction should be carefully considered. While it could help with water storage, combined with the effects from clmate change it could damage river and ecosystem functions.

Recommended adaptation measures for water resources

A clear legal framework is crucial to support planning and the implementation of adaptation measures. Here cooperation in implementing the Water Framework Directive (2000/60/EC) together with the Flood Risk Directive (2007/60/EC)is an important vehicle to streamline climate change adaptation activities for water resources. Adaptation measures can be an integral part of river basin management plans. Such adaptation measures could include non-technical actions such as floodplain restoration, afforestation of catchment areas, adjustment of permits for water removal and use and pollution discharge. Other actions include the management of catchment land use to reduce nutrient loading and soil erosion, setting up warning systems and awareness programmes, as well as technical measures like dams, dikes or retention reservoirs. Other mountainous areas like the Alps provides lessons in increased efficiency of water use, infiltration and water saving.

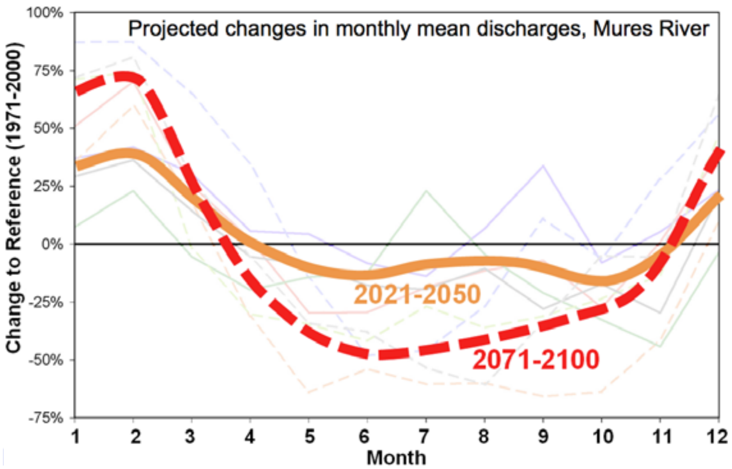

Figure 14: *Expected changes in monthly mean discharges of a large Carpathian river (Mures) (averaged model projection) (source: CarpathCC).*

Adaptation Action: Rainwater Harvesting

Increasing the water-holding capacity of the soil and harvesting rain can be used as an anti-flood measure as well as to reduce droughts. Typically water harvesting combines more technical interventions such as the building of depressions or small dams with biological elements like the use of vegetation-borders, grassy belts, belts of shrubbery and trees and protection and/or restoration of infiltration areas.

The average cost to prepare and implement comprehensive flood prevention and anti-erosion measures based on water conservation or harvesting depends on the character and morphology of the land. Inexpensive measures could be implemented and maintained by landowners and would create employment. The average costs for implementation comprehensive flood prevention measures based on water conservation or harvesting and anti-erosion measures for a square kilometre of land represents 0.1% of the annual GDP of a country multiplied by the number of years needed for implementation and then divided by the area of the region (in km^2).

On the benefit side, rainwater is harvested in watersheds in such a way that ecosystems can “produce” enough good quality water for humanity, food and nature, can purify polluted water, and can reduce the risk of natural disasters like floods, droughts and fires.

Examples of rainwater harvesting (source: Kravcík et al. (2007)

Forests and Forestry

The Carpathians contain the largest continuous European forest ecosystem. The region provides an important refuge and corridor for the migration of diverse species and harbours exceptional biodiversity. Recently, forest damage in Carpathians has been increasing. Wind damage followed by insect pest outbreaks (Figure 15), outbreaks of defoliating insects as well as the increasingly recognised effects of drought have been observed to compromise the stability of Carpathian forest ecosystems and the sustainability of forest ecosystem services.

Climate change is expected to make this situation worse although interactions between climate, forest disturbances and forest management are not yet thoroughly understood. Climate projections imply that anticipated change in several climatic variables, mainly those related to drought, may exceed limits threatening the survival of several currently dominating forest tree species across large areas of the Carpathians. At the same time, observed and projected changes in forest pests and disease distribution as well as potential influx of new pests may critically affect some Carpathian forests.

Recent projections imply a loss of the present value of European forestland by the year 2100 of between 14 and 50%. Combined with the impacts of climate change on the environment, this may lead to adverse effects on the economies of the region. Carpathian countries do not possess sufficient capacity to take efficient measures to help forests to adapt to anticipated changes in climate. None of them has yet directly addressed climate change in its forestry legislation (although the issue is usually included in national strategies). Cross-sectoral cooperation in dealing with climate change is limited and conflicts among sectors are frequent. Adaptive capacity related to socio-economic development is

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substantially lower in the Romanian and Serbian part of the Carpathians compared with the Western Carpathians. Along with increasing regional climatic exposure towards the southeast, this implies high vulnerability of mainly the eastern and southern forests (Figure 16).

Recommended adaptation measures for forests and forestry

Cornerstones of a proposed system of adaptation measures, which should be geared to practical forest management and legislation, include:

- Ensure risk assessment in forest management planning is carried out. This is becoming increasingly important and there is a need to change the traditional timber production-oriented management towards an adaptive risk-responsive management;
- Promote concepts of continuous-cover-forestry and close-to-nature forestry to increase adaptive capacity of forests and lower anticipated risks;
- Increase the proportion of drought tolerant species, mainly oaks, including Mediterranean species in exposed sites;
- Reduce the proportion of vulnerable water demanding conifers and beech at lower elevations;
- Consolidate and harmonize forest monitoring systems, in order to provide information to support adaptive forest management;
- Monitor trans-national invasive pests and diseases;
- Avoid forest fragmentation and stress maintaining the connectivity of larger forest areas to support species' natural migration and gene flows; Increase awareness of the indispensable role of forests in integrated watershed management, particularly in biodiversity maintenance, water regulation and erosion control; and
- Strengthen mainstreaming of climate change issues into all aspects of forestry – from education to policy and from monitoring to management planning.

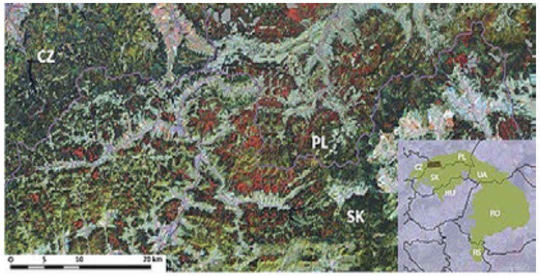


Figure 15: *Forest cover change in the Western Carpathians Beskids Mountains between 1994 and 2010 evaluated using satellite imagery. Red-coloured areas indicate changes in forest cover due to felling of trees infested by bark beetles.The brown square to the right indicates region's position in the Carpathians (source: CarpathCC).*

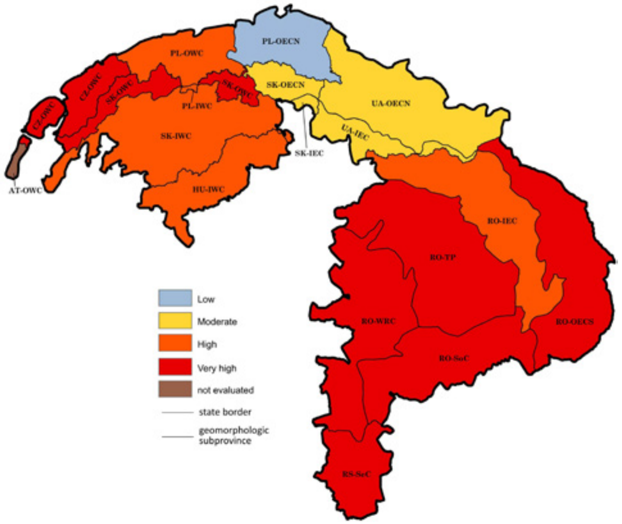
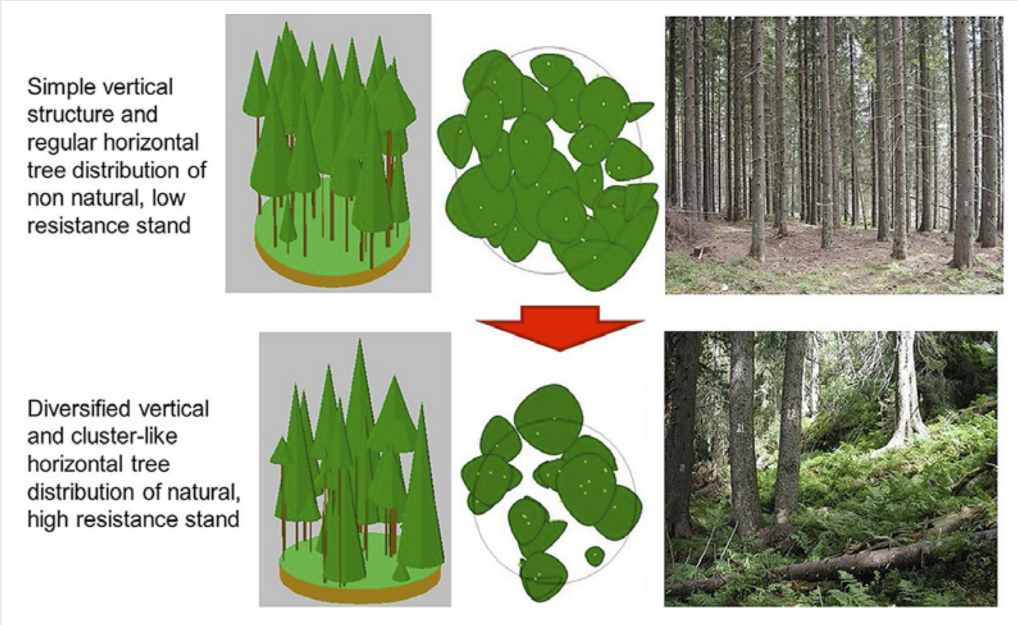


Figure 16: *Vulnerability of Carpathians forests to climate change evaluated in the frame of geomorphologic units on the basis of several indicators of climatic exposure, forest climatic sensitivity and social-economic adaptive capacity (source: CarpathCC).*

Adaptation Action: A Compensation Scheme for Forest Protection

Compensation schemes offer incentives in exchange for better land management. In a "Payment for ecosystem services" (PES) scheme compensation payments are tied to measures that provide ecological services. In forestry one such measure is to reduce the share of spruce and increase planting of fir, larch and mountain sycamore. Prolonging cutting intervals is another example. These measures strengthen forest resilience and protect against pest outbreaks triggered by extreme weather. In addition, incentives are created to reduce over exploitation and illegal logging.

Carpathian forests face a range of pressures including over exploitation through logging. The absence of an equitable system of compensation payments encourages local forest owners to overcut. Compensation for harvesting restrictions within private forests would create an incentive for owners to reduce harvesting. Payment for ecosystem services has been discussed in the Rodna-Maramureş region. As financial resources are limited, it was advised to give implementation priority to Protected Areas. In Rodna about 40% of the total of 23,000 hectares of forest is protected.



An extended cutting regime leads to adaptation of forest structure (source: CarpathCC Project presentation)

Wetlands

The Carpathian wetlands are very fragile and sensitive to natural as well as anthropogenic pressures. Over 75% of wetlands at higher elevations have been converted for farming or were lost due to hydro or tourist infrastructure development. The remaining wetlands are often degraded and poorly protected. High altitude wetlands are crucial for both flood management (they act as sponges and thus level off flood peaks in winter and low flows in summer) and for biodiversity. Further wetland loss would reduce habitats for many water dependent plant and animal species and lead to habitat fragmentation on a regional scale. This would endanger migrating birds that depend upon a network of wetlands along their flight routes.

Little research exists on the effects of climate change on Carpathian wetlands, yet we can draw on studies from other mountain areas. Most reported are the effect of increasing temperatures and precipitation changes. Increased temperatures can lead to drying out of wetlands, compounded by higher incidence of drought. If precipitation declines and groundwater is extracted for human needs, shallow and temporary areas, such as depressional wetlands that often harbour rare species, can be lost entirely. In addition, climate change will affect the carbon cycle and the emission and uptake of greenhouse gasses by wetlands.

The most vulnerable wetland habitats are peat lands because they have limited resilience to climate variability and are sensitive to human activities and changes in land use. Less vulnerable are halophytic habitats (where plants are adapted to saline soils), steppes

© Herczeg Zoltan


Divici Pojejena Wetlands, Romania

© Parcul Natural Portile de Fier

Adaptation Action: Maintaining Wetlands and Riperian Forests

Riparian forests are the natural type of vegetation along streams and rivers, and are strongly influenced by flooding and high groundwater levels. Due to a variety of conditions, they count among Europe's most species-rich habitats. Near-natural riparian forests have virtually disappeared from Central Europe as many have been cleared and transformed into pasture. Riparian forests have high recreational value, store water and improve groundwater quality. Depending on their size and condition, they can also contribute to flood protection. As ecosystems associated with flowing waters, they are extremely important for ecological connectivity. Measures to maintain and develop riparian forests include planting trees and maintaining small water bodies and other natural features. These steps are being taken for the wetland in Divici Pojejena, Iron Gates National Park, Romania.

The benefits of maintaining alluvial forests are high, whereas the cost is low, according to the regional Caras-Severin Environmental Protection Agency. The area in questions includes the Divici-Pojejena wetland and also other wetlands along the Danube. Multiplying the unit cost by the number of hectares leads to a total project cost of 55,000 euro. Benefits include reducing nutrients and pollutants, erosion control, species diversity and offering a wintering and nesting habitat for birds, including protected species such as the pygmy cormorant and ferruginous duck.

and marches. These habitats can adapt to climate fluctuations, yet are highly sensitive to human activities and changes in land use. The lowest vulnerability is found in habitats already subjected to regular flooding, subterranean wetlands and some riverbank and water habitats. They are most likely to be able to cope with even more extreme fluctuations in climate. However, human intervention can represent important threats also in this case.

Recommended adaptation measures for wetlands

Adaptation strategies for wetlands are closely linked to measures aimed to make hydrological systems more resilient. Maintenance and restoration of wetlands in higher altitudes plays an essential role in increasing retention capacities and reducing impacts of droughts and excess precipitation. Floodplain restoration, including the recreation of wetlands, will restore important functions such as water purification, nutrient retention and will be a buffer for droughts and floods. Thus protection of wetlands is a "no-regrets" strategy even in times of high uncertainty about the extent and location of specific impacts of climate change. In places where wetland restoration is difficult, it is highly recommended to reduce external non-climate pressures such as land-use change and pollution. Improving connectivity between wetlands and water bodies can help species to move, as well as preserve habitat heterogeneity and biodiversity, which can provide genetic diversity for successful adaptation. Priority adaptation measures include:

- Develop and support ecosystem monitoring systems, and monitor the state of waters and aquatic ecosystems in the region;
- Integrate wetland protection with flood control practices and support programmes aiming for wetland and peat land restoration, floodplain rehabilitation and creation of new wetlands and lakes to enhance local water retention capacity and support biodiversity;
- Restore river and floodplains; and
- Develop small-scale water retention in lowland riparian forests.

Grasslands

The Carpathians are characterized by a wide variety of traditionally managed, multifunctional landscapes. Such landscapes are often dominated by pastoralism and are therefore principally comprised of grasslands and pastures whose detailed ecological structure is typified by the 'green-veining' of hedges, woodland, forests and watercourses. Such landscapes have strong cultural associations, provide a wide range of ecosystem services and associated economic benefits, and are rich in wildlife and biodiversity. Ecosystem services associated with grasslands include high quality food (milk, cheese, meat) and wool, clean water, mitigation of climate change by absorbing green house gases, pollination, biodiversity conservation, recreation, tourism and important aesthetic and cultural values.

Carpathian grasslands host 40 species listed in the EU Habitat Directive, 11 of which are endemic. In total, 19 grassland habitat types of European importance occur in Carpathians. However, these landscapes and grasslands are under serious pressure. Most significant are land abandonment, forestry and intensified agriculture. As well, grasslands in the Carpathians are particularly vulnerable to the impacts of climate change.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Grasslands will be and are already affected by climate change through changes in CO_2 concentration, in mean temperatures, in precipitation and in the occurrence of extreme weather conditions. In addition, grasslands will be negatively affected by the climbing treeline. Encroachment of mountain meadow area has already been observed, mostly by coniferous species at upper elevations. Changes in species composition occur because of the appearance of 'new' species rather than due to the intolerance of 'original' grassland species to climate change. As the changes proceed, species diversity may increase in the first years (when the 'old' and 'new' species are present), but then decreases as the new species taking over the habitats. Habitats on calcarous substrate – the most species rich habitats – are found to be more sensitive, thus more threatened, than vegetation on other substrates. Nardus grasslands for example, are less sensitive, that Festuco-Brometelia grasslands. Yet, it is very difficult to make accurate projections as drivers interact with each other and can reinforce or counteract specific impacts.

Grasslands have been traditionally maintained by grazing and a cutting or burning regime. Today, a significant part of semi-natural grassland habitats in the Carpathians is either abandoned or overgrazed, both for economic reasons. Overgrazing results in loss of species diversity and without proper management grasslands are likely to succumb to colonisation by scrubs and forests because coarse herbs and grasses outcompete more fragile and rarer species.

Recommended adaptation measures for grasslands

Adaptation measures were chosen after consultation with stakeholder groups and an assessment of relevant policies and regulations in the Carpathian countries. They took into account the costs and benefits and long-term sustainability of the proposed measures. Measures focus on agro-environmental programmes, ways to facilitate sustainability and ecosystem services.

The task of the agro-environmental programmes is to harmonize relations between the production of food and the conservation of the environment. A parallel goal is to contribute to the maintenance of village communities. The general aim is to issue compensation payments for environmental friendly management practices, including

- Reducing anthropogenic pressures on the environment in these areas;
- Maintaining and increasing the biodiversity of agricultural areas, and to especially conserving ecosystems which increase ecological stability and biological diversity, and which protect endangered types of flora and fauna, and the genetic diversity of crops and seeds;
- Enhancing the protection of soil against degradation, especially erosion;
- Supporting traditional agricultural methods in areas with a high natural value; and
- Enhancing the socio-economic development of the village.

A management measure, applicable to selected Carpathian grasslands, is the restoration of open vegetation. After abandonment most grassland gradually turns back into forest. Removing trees (for instance Robinia) and shrubs should be the first priority in restoration. Additionally good management will further enhance the development towards mature seed-producing individuals. This includes management through grazing and mowing, rather than mulching or fertilization. Abandonment is not recommended for conservation either.

Traditional markets do not value many of the benefits provided by ecosystem services. For example, pure drinking water can be extracted from mountain areas at almost no cost and the seemingly endless Carpathian landscape views are free of charge. As a consequence, the current economic market model leaves small-scale traditional farms, which are an important economic activity in the Carpathian region, at a disadvantage. These landscapes, and the farms associated with them, deliver multiple services and should be supported.. There is potential to mainstream the values of semi-natural grasslands across EU policies (e.g. through the Water Framework Directive) and programmes and funding (e.g. the Common Agricultural Policy and the EU Cohesion Policy).. The Carpathian Convention could be a critical vehicle to stimulate this mainstreaming into different policies.

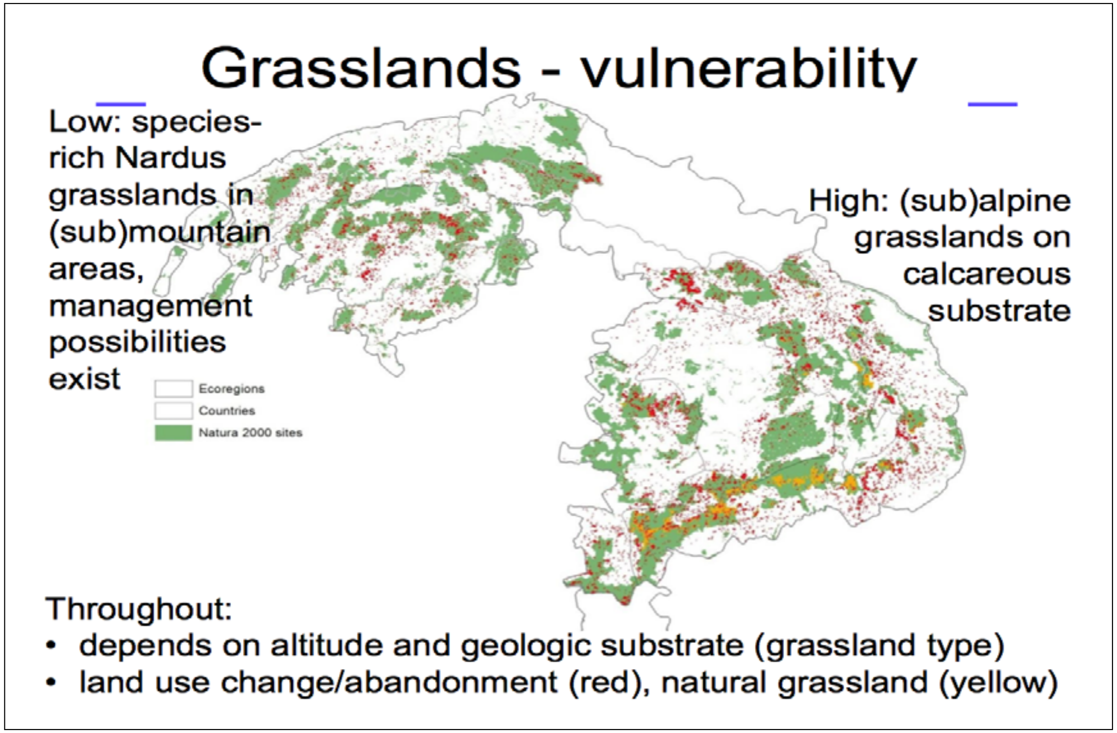

Figure 17: *Grasslands vulnerability to climate change in the Carpathians (source: CarpathCC).*

Adaptation Action: Restoration of degraded grasslands

The Bükk region in Hungary is the part of the Vár-Hegy-Nagy-Eged Natura 2000 Habitat Directive Site, which is currently being restored by the KEOP project. Before the start of the restoration project in 2012 the case study area was essentially an abandoned grassland being overgrown by shrubs. The KEOP project aims at restoring this site to mowed grassland with fruit trees. The targeted Natura2000 categories are 6210 'Dry and semi-dry calcareous grasslands, sub-mediterranean to sub-continental in character' and 6240 'Sub-continental steppic grasslands with vegetation of the Festucion valesiacae alliance and related syntaxa'. The interventions started in 2012 by manually removing the bushes and shrubs (costs 1,400 euro/ha). This was followed by the mechanized crushing of stalk left in the soil (costs 340 euro/ha). The remaining grasslands are preserved by mowing on a regular basis (grazing will not be allowed because of the drinking water wells downstream in the valley) (initial costs during 3 years period 500 euro/ha). In addition, fruit trees are being planted. Planting of traditional, autochthonous (endemic) fruit trees is envisaged. These species are much more resistant against environmental stresses than the new breeds. The National Park purchased a total area of 4.2 ha within the frame of the KEOP project for 1,700 euro/ha. The costs of planting fruit trees (apple: 159, quince: 494, cherry: 2, pear: 28, plum: 112): 3,745 euro. The estimated annual yields of these fruit trees is 37,798 euro. Other benefits include water infiltration and provisioning, improved pollination capacity, species diversity and touristic value

Agriculture

Despite contributing less than 10% to GDP in the Carpathian countries, agriculture plays an important role in regional economies. Agricultural land covers over one third of the Carpathian region and the proportion of population working in agriculture can be as high as 50%. As well, agriculture continues to have a major effect on the landscape and biodiversity of the Carpathians. At the same time, the structure of the agricultural sector is changing. Overall crop and livestock production is declining and abandoned cropland lies fallow. This trend is expected to continue. Only in the lower parts of the Slovak Carpathians is intensive agriculture practiced. In the rest of Carpathian countries small-scale agriculture prevails. Traditionally managed agriculture has resulted in a wide variety of landscapes in most parts of the Carpathians.

In some cases, agriculture will experience significant pressures due to changing precipitation, temperature, and length of seasons. Agriculture may become feasible at higher altitudes. In some parts of the Carpathians maize and wheat yields will decline, while elsewhere sunflower and soya yields might increase due to higher temperatures and migration of these crops northward. Likewise, winter wheat is expected to increase. In general a shift during spring planting towards winter crops will be possible. Unfortunately, vulnerability to pests is predicted to rise, and increasing productivity losses are expected as a result of soil erosion, groundwater depletion, and extreme weather events. Deeper analysis of socio-economic trends is necessary to identify the most vulnerable areas in the Carpathians but preliminary results show that small-scale farmers in remote villages in Romania and Serbia could be among the most vulnerable. Pastures in the Carpathians are especially vulnerable through the combined impacts of climate change and socio-economic dynamics. In particular, the pastoralists needed to maintain the grasslands and implement potential adaptation measures are abandoning grazing and land management activities. The traditional mixed agro-ecosystems in the Carpathians may disappear through a combination of land abandonment, land use change and increased advance of forest areas encouraged by climate change.


© Pieniny National Park

Recommended adaptation measures for agriculture

Farmers are always adapting to changing conditions. For small-scale farmers potential adaptation options can include changes in sowing dates and crop varieties, improved water-management and irrigation systems, adapted plant nutrition, protection and tillage practices. To achieve the broader goal of sustainable agriculture and rural development in a changing climate, policies should support the autonomous adaptation of farmers. Taking into account developments in the Carpathian region (including land abandonment, overgrazing, aging population, and limited budgets for government action) the following management measures are suggested:

- Support small-scale traditional farms as important economic activity delivering multiple ecosystem services;
- Develop and facilitate agro-environment programmes which are critical to maintain and enhance biodiversity and viability of semi-natural grasslands and mixed agro-ecosystems. This requires among other things location-specific solutions for unresolved property rights, especially for grasslands used for common grazing; and
- Connect local communities, non-governmental organizations, environmental activists and researchers to promote the countryside as an attractive place to live as well as a favourable business environment. The role of volunteers and activists should not be underestimated because they can aid with reporting, data collection, and with elaborating on and implementing ideas.

Traditional agricultural practices in the Tarnava Mare region

Adaptation Action: High Nature Value Farming

High nature value farming (HNV) supports farming activity and farmland that has high biodiversity or contains species and habitats of conservation concern. The Romanian Government has implemented a High Nature Value Grassland agri-environment measure as part of its National Rural Development Plan (NRDP) in an attempt to limit both agricultural abandonment and intensification. Farmers can voluntarily enter into a five-year agreement and receive payments, currently set at €124 per ha, in return for adhering to a specified set of management requirements. These include, for example, a ban on the use of chemical fertilizers. Farmers can also apply for the Traditional Farming option whereby additional payments can be obtained in return for not using any mechanization.

In the long run, farming can be preserved through sustainable grassland management. An example is the Tarnava Mare region in Romania, an area consisting mostly of small-scale semi-subsistence farming where the meat, dairy products and honey produced are an essential source of local food. A pilot agri-environment scheme helped local food production and will strengthen biodiversity. For example butterflies will benefit from sustainably managed grasslands where many wild flowers will provide either nectar for adult butterflies or larval food plants. The pilot found that, as well as agri-environment payments, actions were needed that support local markets. These included improvement of milk collection points for small-scale milk producers in the Tarnave region and the creation of a brand for local products. Opportunities were also created for agro-tourism. The adaptation measure thus creates a "multiplier effect" whereby tourism becomes an extra form of "payment" to local people for landscape conservation

Tourism

Many famous destinations can be found in the Carpathian Mountains, such as the Tatras in Slovakia, Bucegi Mountains and Prahova Valley in Romania, the Iron Gates in Romania and Serbia, and a long list of fortresses, castles, lakes, pristine forests, spas and baths and so on, adding up to approximately 31 million overnight stays throughout the study area in 2011. Tourism is a very important economic sector and generates 7 to 12% of the Carpathian Region's GDP.

In a tourism vulnerability assessment, temperature and precipitation data were modeled to 2050 and exposure, sensitivity and adaptive capacity of the relevant tourism activities were carefully examined. Besides quantitative methods, surveys were completed in a few Romanian and Slovakian regions on the connections between climate change and tourism. In the case of the winter sports, potential snow depth and snow reliability were modeled to 2050 as well.

In the short term at least, changes in the tourism industry depend more on the general state of the region's economy than on climate change. In fact, the study suggested that total number of overnight stays and revenue could increase slightly (less than 1%, that is between 50 and 100 thousand additional overnights, or the equivalent of a small ski resort) due to climate changes in the Carpathian region. At the same time, significant differences were found depending on the region or activity analyzed. There are several positively affected tourism activities (ecotourism, summer, health, and vocational tourism). Fishing, hunting and winter sports are affected more or less negatively. However, snow cover and snow depth changes will not cause as much of an effect on the tourism as formerly supposed. This is because the Carpathians region has a wide range of tourism activities and winter sports are not as important as, for example, in the Alps. Due to the lower altitude, ski resorts appear better prepared for changing snow conditions.

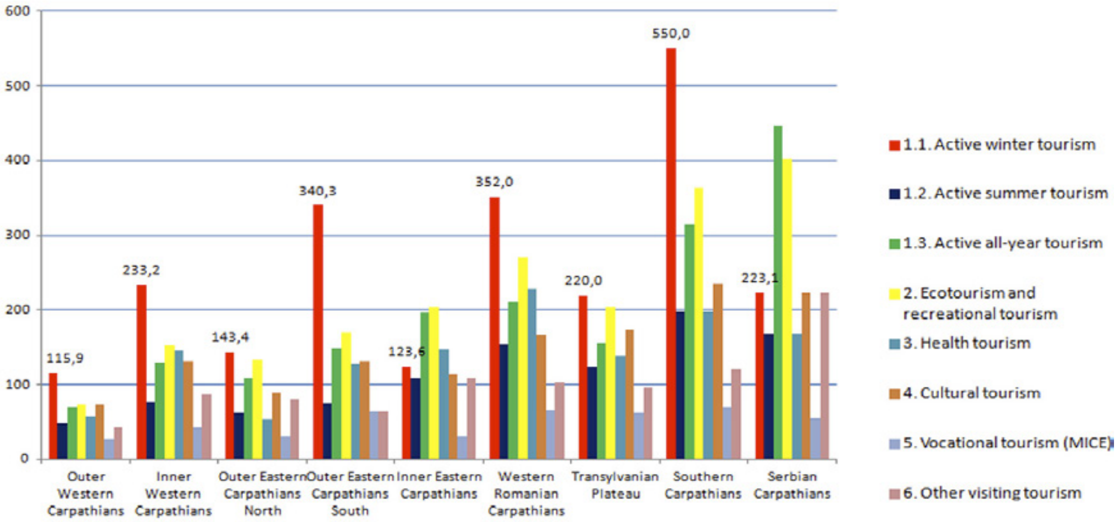

Figure 18: *Vulnerability of the Carpathian region (source: CarpathCC).*

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Adaptive capacity is more or less equivalent to the level of general economic development. Therefore study results confirmed a "southeast-northwest slope" of the vulnerability (higher in the northwest, lower in the southeast). The vulnerability of tourism activities was ranked for each region. Based on this analysis, if the vulnerability number remains under 100, the analyzed activity is scarcely vulnerable. Between 100 and 200, the activity is moderately vulnerable. Above 200 vulnerability is high (Figures 18, 19). The scale of vulnerability of the specific activities can be reduced through special adaptation measures.

It is important as well to highlight the fact that climate related change such as landscape degradation, wildfires and flash floods have the potential to seriously affect tourism in near future and could be enough to counteract any potential positive effects.

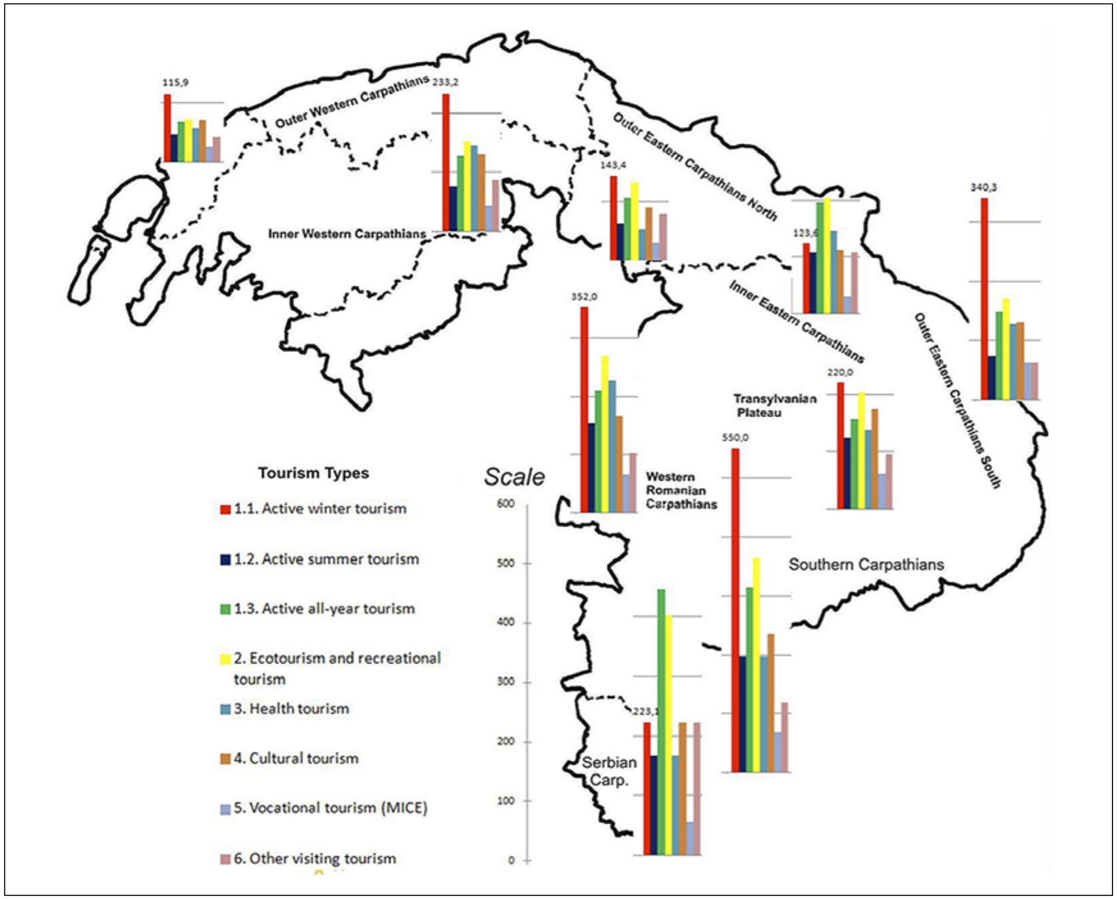

Figure 19: *Vulnerability map of the Carpathian regions (source: CarpathCC).*

Additionally, large regions are suffering from social degradation, which can lead to damages to the landscape, such as in East-Slovakia, North-Hungary, and Romania, where the impoverished communities erode the landscape by illegal logging, garbage deposits etc. Social tensions and increasing criminality can also negatively affect the tourism sector.

Our survey found the image of old, winter sport-based resorts (like Sinaia, Predeal, Poiana-Brasov or Harghita) is slowly changing. New, all-year activities and services like climbing, trekking, wellness, etc. and new accommodations partly replace the lost earnings from winter sports. This diversification means that tourism in the higher mountains is not overly vulnerable. Beyond this, higher ski resorts in South-Carpathians and in the Tatras seem to be moderately concerned about climate change impacts to 2050.

Recommended adaptation measures for tourism

- Improve accessibility due to the growing demand;
- Develop year-round, resilient destinations with good accommodations (e. g. wellness and conference hotels);
- Support climate-friendly winter sport projects (e. g. alternative design of ski pistes);
- Develop relaxation and entertainment activities (e. g water-based aquaparks, sport facilities);
- Develop ecotourism, health tourism, active tourism (such as cycling); and
- Continue to diversify resorts and markets

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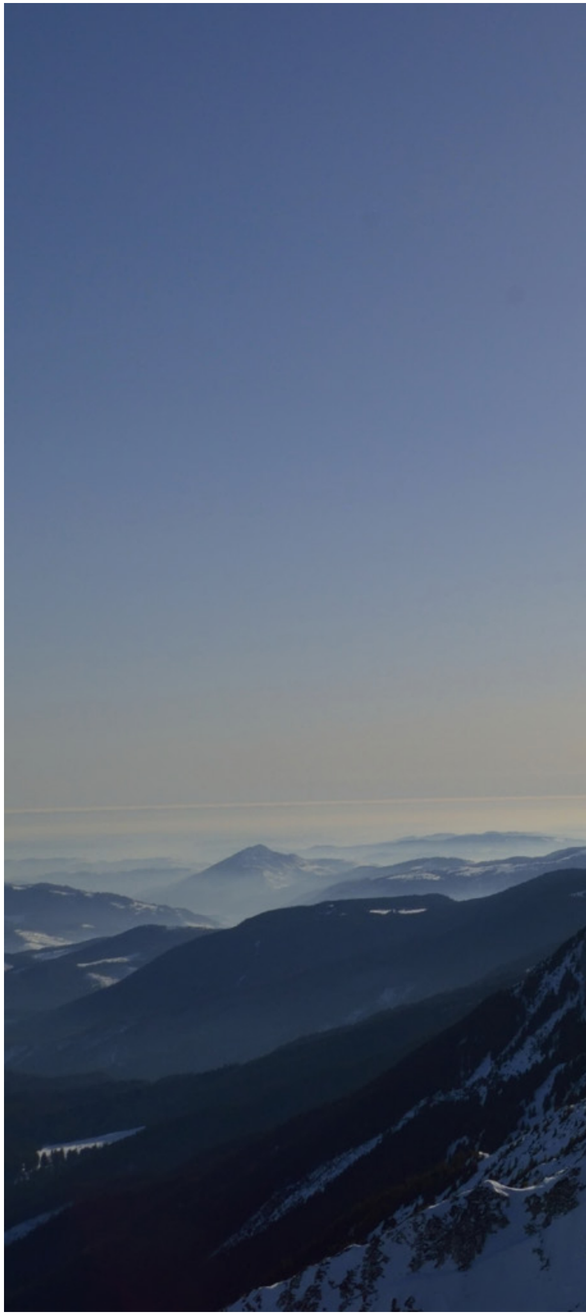


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Conclusions and Recommendations

The Carpathian Convention is responding to the threats from climate change and the need to adapt through the **"Strategic Agenda on Adaptation to Climate Change in the Carpathian Region"** to be endorsed at the Fourth Meeting of the Conference of the Parties to the Carpathian Convention (COP4) 23-26 September 2014 in Mikulov.

A Carpathian Convention Working Group on Climate Change has been established under the Convention with the mandate to advise the Parties and the Secretariat on policies, actions, research, data gathering and projects relevant for mitigating and adapting to climate change impacts in the region. The Working Group is responsible for coordinating climate change adaptation policies and projects in the Carpathians with other relevant government and non-government organisations.

The Carpathian Convention Working Group on Adaptation to Climate Change developed a Strategic Agenda on Adaptation to climate change in the Carpathian Region, the aim of which is to assist Member States of the Carpathian Convention, local and regional authorities and other stakeholders involved in management of the Carpathians to formulate responses to climate change as a way to secure the sustainable development in the region. The Agenda has been discussed at meetings and workshops with Country representatives and observers to the Carpathian Convention as well as other interested stakeholders.

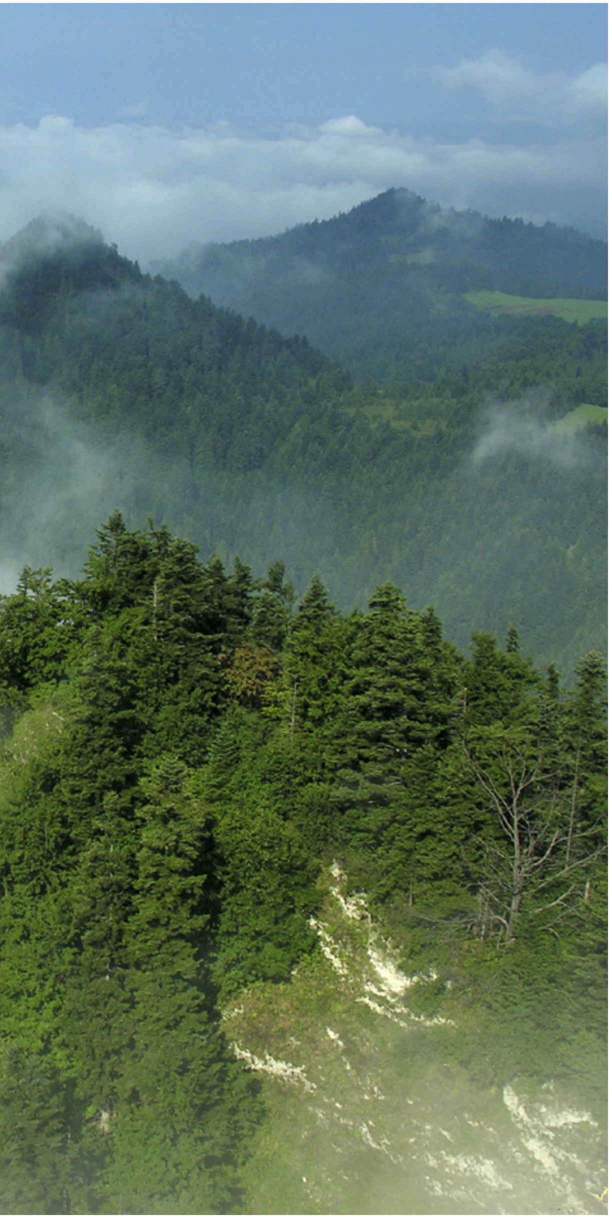
The Strategic Agenda includes recommendations for policy development, institutional change and ecosystem-based adaptation measures. By adopting the Strategic Agenda, the Conference of the Parties (COP) calls upon Contracting Parties, local and regional authorities and other stakeholders involved in management and development of the Carpathian region to formulate policies and design strategies to adapt to climate change impacts and to mitigate its adverse effects.

The following main conclusions and recommendations, based on the outcomes of the projects described in this report, are further supported by the Strategic Agenda on Adaptation to Climate Change in the Carpathian region[3]

Strengthened knowledge and information sharing on climate change and adaptation in the Carpathians

- Increase the awareness that climate change and natural disasters in mountain regions such as the Carpathians pose to sustainable development. Climate change has severe socio-economic and environmental impacts on human- wellbeing and on both mountain and downstream communities.
- Continue to pool efforts to raise awareness for the issue at the level of decision-makers through innovative communication tools and events.
- Strengthen monitoring activities (including development of monitoring systems with common methodology) and enhance data availability, accessibility and harmonization related to climate change and natural disasters.
- Prepare a systematised, easily comparable dataset of climatological and climate impact related data between countries.
- Develop modelling activities for future research in the region and/or adapt existing models and evaluate them based on the actual local conditions.
- Map and assess Carpathian ecosystems goods and services.
- Exchange information and experience with other mountain regions as well as neighbouring areas that are facing similar problems.

3. For further information and the full text of the Strategic Agenda, please visit www.carpathianconvention.org



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Policy responses to create a path to a climate-proofed Carpathian Economy

- Mainstream climate change policies and objectives into relevant national plans/policies and development plans to ensure that investment is not wasted as a result of changing climatic baseline conditions.
- Develop, monitor and update national adaptation strategies.
- Using an ecosystem-based management approach, recognize that sustainable use of natural resources and ecosystems in mountains limit their ability to curb the impacts of climate change and natural hazards.
- Several opportunities and recommended measures are best planned regionally rather than nationally. Many of the tools and capacities necessary for climate change adaptation such as the designation of and mapping of future refuge habitats for grasslands and wetlands are best possible at the transnational level.
- At the regional level, regional cooperation platforms such as the Carpathian Convention are an important tool to integrate different countries' policies of nature conservation, river basin management, sustainable agriculture, etc. This will lead to a further strengthening of the Carpathian region.
- Create and improve adequate policies and frameworks particularly at the transboundary level such as in the context of the Carpathian Convention building on the endorsed "Strategic Agenda on Adaptation to Climate change in the Carpathians".
- Climate change considerations need to be also built into future activities and work of respective Carpathian Convention Working Groups, work plans and decision-making.

Responses at the institutional and organizational level

- Based on the experiences of other mountain regions such as the Alps, a designated pan-Convention policy-, funding-, coordination and communication context for climate change adaptation would be desirable.
- In the context of the EU Strategy for the Danube Region and future programme priorities, avoid duplication of adaptation measures between the Carpathian and Danube processes and integrate Carpathian objectives into the Danube river basin management planning. Further steer the Region's Development Towards a Climate-Proofed Carpathian Space.
- A key action is to create flexible and equitable financial instruments that facilitate benefit and burden sharing supporting different sets of better-adapted new activities.

Future Climate Change adaptation measures

The following actions are recommended for prioritized implementation and represent initiatives that would act as a practical and inspiring demonstration of adaptation in the region.

- Develop a capacity building Programme which draws on, and enhances, the connectivity of the Region.
- Enhance information management and strengthen awareness raising and communication.
- Climate proof of infrastructure and investments.
- Develop forestry measures for climate change adaptation.
- Develop flood risk and drought mitigation measures based on natural solutions (for example wetlands conservation and restoration).
- Creating more dynamic biodiversity management.
- Deliver technical assistance and build capacity at the local level to develop adaptation measures.
- Support the establishment of a permanent Carpathian Convention Working Group on Climate Change to continue to advice the Secretariat and the Parties to the Carpathian Convention on relevant responses needed and projects and initiatives to be taken.

References

Gervais, M. , G. Luciani, M. Onida (2013). "Sustainable mountains – The Alps and the UN " in P. Bußäger and C. Gsodam (eds.) Multi-Level- Govrenance in Alpenraum (New Academic Press, Wien).

Hanewinkel, M., D. A. Cullmann, M. J. Schelhaas, G. J Nabuurs, N. E. Zimmermann, (2012). "Climate change may cause severe loss in the economic value of European forest land." Nature Climate 3.

Hlásny, T., and Z. Sitková, eds. (2010). Spruce forests decline in the Beskids. (Zvolen: National Forest Centre – Forest Research Institute Zvolen & Czech University of Life Sciences Prague & Forestry and Game Management Research Institute Jíloviště – Strnady).

Hlásny, T., Cs. Mátyás, R. Seidl, L. Kulla,, K. Merganičová, J., Trombik,, L, Dobor, Z, Barcza, B. Konôpka (2014). "Climate change increases the drought risk in Central European forests: What are the options for adaptation?" Lesnícky časopis – Forestry Journal 60.

IPCC (2013). Climate Change 2013. The Physical Science Basis. Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press.

Jacob, D. et al. (2014): EURO-CORDEX: new high-resolution climate change projections for European impact research. Regional Environmental Change, Vol. 14, 563–578

Kuemmerle, T., O. Chaskovskyy, J. Knorn,, V.C. Radeloff, I. Kruhlov, W.S. Keeton, P. Hostert (2009). "Forest cover change and illegal logging in the Ukrainian Carpathians in the transition." Remote Sensing of Environment 113.

Kravcík, M., Pokorny, J., Kohutiar, J., Kovác, M., Tóth, E. (2007) Water for the Recovery of the Climate - A New Water Paradigm, publication from partner cooperation between the People and Water NGO, the Association of Towns and Municipalities of Slovakia, ENKI and the Foundation for the Support of Civic Activities.

Lakatos, M., Szentimrey, T., Bihari, Z., Szalai, S. (2013): Creation of a homogenized climate database for the Carpathian region by applying the MASH procedure and the preliminary analysis of the data, Időjárás, Vol. 117., No. 1., 143-158

Lakatos, M., Z. Bihari, T. Szentimrey, S. Szalai and the CARPATCLIM project Team: Climate of the Carpathian Region - summary of the CarpatClim project, 3th EMS Annual Meeting & 11th European Conference on Applications of Meteorology (ECAM) | 09 – 13 September 2013, Reading, United Kingdom

Page, Nat et al [n.d.] Linking High Nature Value Grasslands to Small-Scale Farmer Incomes: Târnava Mare, Romania. Fundatia ADEPT, Mures Romania. (http://www.mountainhaymeadows.eu/online_publication/files/14-linking-high-nature-value-grasslands-to-small-scale-farmer-incomes-tarnava-mare.pdf. Accessed 5 September 2014.)

Regional Environmental Center for Central and Eastern Europe and the European Academy Bolzano, Handbook on the Carpathian Convention (2007).

Szentimrey, T. (1999): Multiple Analysis of Series for Homogenization(MASH), Proceedings of the Second Seminar for Homogenization of Surface Climatological Data, Budapest Hungary; WMO,WCDMP-No. 41, pp. 27-46.

Szentimrey, T. and Bihari, Z. (2007): Mathematical background of the spatial interpolation methods and the software MISH (Meteorological Interpolation based on Surface Homogenized Data Basis). Proceedings from the Conference on Spatial Interpolation in Climatology and Meteorology, Budapest, Hungary, 2004, COST Action 719, COST Office, 17–27

Further reading

Barcza, Z., Bodea, L., Csoka, G., Dodor, L., Galvánek, D., György, D., Hidy, D., Hlásny, T., et al. (2013) In-depth study on the impacts of climate change threats on ecosystems (Final report - Module SR2). CarpathCC, report to European Commission - DG Environment. REC - The Regional Environmental Center For Central Eastern Europe, AQUAPROFIT, INCDPM, CAR HAS, ARTELIA, Budapest, HU, http://carpathcc.eu/node/35.

Csete M., T. Pálvölgyi, G. Szendrő (2013). Assessment of climate vulnerability of tourism in Hungary. Regional Environmental Change 13. 1. 1–15. Published online: 06. 02. 2013.

Peters, R., Lambert, S., Kőpataki, É., Varga, R., Arany, I., Iosif, A., Moldoveanu, M., Laslo, L., Interwies, E., Görlitz, S., Kondor, A. and Orosz, B. (2013) In-depth study on the impact of climate change on ecosystem-based production systems (Final report - Module SR3). CarpathCC, report to European Commission - DG Environment. REC - The Regional Environmental Center For Central Eastern Europe, ARCADIS Belgium N.V., Budapest, HU, http://carpathcc.eu/node/35.

Surugiu, C., A.I. Dincă, D. Micu (2010). Tourism Destination Vulnerable to Climate Changes. – An Econometric Aroach on Predeal Resort. Buletinul Universitatii Petrol-Gaze din Ploiesti, Seria Stiinte Economice 62.

Surugiu, C., M. R. Surugiu, C. Frent, Z. Breda (2011). Effects of Climate Change on Romanian Mountain Tourism: are they positive or mostly negative? European Journal of Tourism, Hospitality and Recreation 2.

Scott, D., J. Dawson, B. Jones (2008). Climate change vulnerability of the US Northeast winter recreation – tourism sector. Mitigation and Adaptation Strategies for Global Change 13.

Wall, G. (2004). "The Tourism Industry: Its Vulnerability and Adaptability to Climate Change." in Beveridge, M., Nelson, J.G. & Janetos, S. (eds.): Climate Change and Ontario's Parks. Proceedings from the State of the Art Workshop: Climate Change and Ontario Parks, 25–27 February 2004, Canada. Faculty of Environmental Studies University of Waterloo. – Ontario Canada Climate Change and Ontario's Parks Research Forum of Ontario.

Werners, S., Zingstra, H., Bos, E., Hulea, O., Jones-Walters, L., Velde, I. v. d., Vliegenthart, F., Beckmann, A., Delbaere, B., Civic, K., Kovbasko, A., Moors, E. and Schipper, P. (2014) Integrated assessment of vulnerability of environmental resources and ecosystem-based adaptation measures (Final report). CARPIVIA, report to European Commission - DG Environment. Alterra - Wageningen UR, ECORYS, ECNC, Grontmij, WWF-DCP, Wageningen, NL, www.carpivia.eu.

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