Climate change vulnerability and adaptation in the Carpathian region

Final Report - Integrated assessment of vulnerability of environmental resources and ecosystem-based adaptation measures

In co-operation with
ECORYS, ECNC, Grontmij and WWF-DCP

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Saskia E. Werners, Ernst Bos, Kristijan Civic, Tomáš Hlásny, Orieta Hulea, Lawrence Jones-Walters, Éva Kőpataki, Aleksandra Kovbasko, Eddy Moors, David Nieuwenhuis, Ilse van de Velde, Henk Zingstra, and István Zsuffa 2014. *Climate change vulnerability and ecosystem-based adaptation measures in the Carpathian region: Final Report - Integrated assessment of vulnerability of environmental resources and ecosystem-based adaptation measures*. Wageningen, Alterra Wageningen UR (University & Research centre), Alterra report 2572. 132 pp.; 37 fig.; 14 tab.; 111 ref.

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Summary

The Carpathian region is a mountainous areas of outstanding natural beauty. The CARPIVIA project together with the CarpathCC project assessed the vulnerability of the Carpathian region to climate change in combination with other anthropogenic pressures. The conclusions presented below are discussed in more detail in the chapters of this report.

Key climate change pressures (temperature and precipitation)
Temperature Change - Rising winter and summer temperatures threaten local and national policy objectives related to agriculture, winter tourism, rural development and a host of economic and social issues. The Carpathian mountains are projected to experience an increase between 3.0 ºC in the north-western part to 4.5ºC in the south by the end of this century. The change in winter maximum is less pronounced than the change in summer maximum.
Precipitation Change - Most studies indicate an increase in winter precipitation and changes in snow cover. Although the mean annual values of precipitation do not show a very clear trend, reductions in summer precipitation are projected of over 20% and increases in winter precipitation in most areas of between 5 and 20% by the year 2100.

Vulnerability of water resources
Reduced snow cover, unforeseen heavy rains caused by climate variability, and changes in precipitation patterns will alter flood regimes and increase the risk of flood events. Extreme high precipitation over a short period of time will add to erosion and the risk of land slides. During drier parts of the year, lower river discharges and droughts are expected to increase. The change in average runoff values for the dry months is between a 4% increase and a 19% decrease until 2050. Overall, a decline in total annual river discharge is predicted for southern and eastern parts of the Danube basin, while western and northern parts might experience increases. In particular, southern parts of Hungary and Romania as well as the Republic of Serbia, are expected to face severe droughts and water shortages. Groundwater recharge is likely to be reduced, whilst more frequent droughts in summertime will reduce low flows and result in water shortages. There may be impacts on the quantity and quality of drinking water for communities dependant on mountain streams.
Annual water temperature is projected to change by 1.7°C between 1971–2000 and 2021–2050. Projections of average water temperature change in the summer months reach 4°C or above. In addition, the number of days with extreme water temperature (>28°C) increases. This would have definite impacts on aquatic ecosystems. There is clear spatial variation in the identified climate-induced trends in thermal and runoff conditions, and consequently in the impacts on aquatic ecosystems. While the northern part of the Carpathian region is insignificantly or moderately affected, the southern part is expected to be highly affected. As opportunities for adaptation are relatively well shared yet depend on financial resources, the southern (sub-)basins are expected to be the most vulnerable as well.

Recommended adaptation water resources
The legal framework is crucial to support pro-active planning and the implementation of adaptation measures. Here the cooperation in implementing the water framework directive could be used to streamline activities. It will offer opportunities for the development and application of adaptation measures in the framework of river basin management plans in order to achieve and sustain good ecological status. Such adaptation measures could include *non-technical measures*, such as floodplain restoration, afforestation of catchment areas, adjustment of permits for water abstraction/water use/pollution discharge, the management of catchment land use to reduce diffuse nutrient loading and soil erosion, warning systems and awareness programmes, as well as *technical measures* like dams, dikes or retention reservoirs. Lessons can be learned from other mountainous areas like the Alps that are aimed at increased efficiency of water use, infiltration and water saving.

Vulnerability of (semi-)natural grasslands

Carpathian grasslands are among the richest grassland biotopes in Europe. Their high biodiversity value is a direct result of hundreds of years of traditional management and animal husbandry. Temperature increases, more extreme droughts and floods, soil erosion and an upward shifting tree line are all expected to reduce grassland quality and coverage, leading to habitat fragmentation and loss of species. Whilst for the time being arable agricultural intensification and abandonment of traditional grazing practices are a more immediate threat, the longer-term impacts of climate change are expected to be severe. Long established and stable grassland communities (e.g. mountain hay-making meadows) are more tolerant to climate change than grasslands with a short history. Maintaining therefore appropriate – usually traditional – management methods is vital. Adaptation measures can only be successful when also striving for an economically viable countryside. Results show that impacts depend on both altitude and geologic substrate. For example, alpine and subalpine grasslands on calcareous substrates are very vulnerable to climate change due to their dependence on soil type and limited opportunities to migrate. Conversely, species-rich Nardus grasslands in (sub)mountain areas are considered moderately vulnerable, as grassland management can moderate impacts. Five main management measures are the most widely applied within the Carpathian, namely; grazing, abandonment, mowing, mulching and fertilization. Grazing and mowing was found to be of high importance to be maintained in the future. However, abandonment as a conservation measure will be less suitable in the future due to forest encroachment and increasing timberline. Mulching and using fertilizers to increase the nutrient input is expected to be less suitable due to the presence of invasive species, which thrive in higher nutrient conditions. Finally, agro-environmental programmes can offer indispensable support for maintaining connectivity and grassland management.

Recommended adaptation grasslands

- Implement agri-environment measures & Natura2000 management plans;
- Diversify species and breeds of crops and animals;Manage through grazing, mowing, not abandonment, mulching, fertilization.

Vulnerability of wetlands

High altitude wetlands are crucial for both flood management (acting as sponges and thus levelling off flood peaks in winter and low flows in summer) and for biodiversity. Increased evaporation will lead to drying out of wetlands, compounded by higher incidence of drought. Further wetland loss would reduce habitats for the many dependent plant and animal species and lead to habitat fragmentation, which could threaten migratory birds and amphibians at a regional scale. The most vulnerable wetland habitats are peat lands, because of their dependency on stable high water levels and thus limited resilience to climate variability, and their sensitivity to human activities and changes in land use. Less vulnerable are halophytic habitats and some types of water and river bank habitats. 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, for subterranean wetlands and for 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 wetlands

- Develop and support ecosystem monitoring systems, network to monitor the state of waters and aquatic ecosystems in the region;
- Integration of wetland protection with flood control practices: Support programmes aiming for wetland and peatland restoration, floodplain rehabilitation and creation of new wetland and lakes to enhance local water retention capacity and support biodiversity;
- River and floodplain restoration;
- Small scale water retention in lowland riperian forests.

Vulnerability of forests and forestry

In forests, increasing temperatures and higher incidences of drought will lead to shifts in species composition, especially at lower altitudes towards more drought-resistant tree species. More frequent and increased drought stress can increase pests and pathogenic damages, as well as damage from fire. The tree-line will move upwards, and the occurrence of species will migrate up- and northwards.

Some species and communities might collapse as a result of these shifts especially where connectivity and ecological corridors are limited. Particularly vulnerable species include spruce at lower altitudes, beech, maple, oak and lime. Increased soil erosion will add to the risk of landslides in lower mountain areas. Assessment indicates high to very high forest vulnerability in most of the Carpathians. Only the Ukrainian Carpathians and Polish part of the Outer Eastern Carpathians were rated at moderate to low vulnerability. Different factors determine forest vulnerability across the Carpathians. High forest vulnerability in the Western Carpathians (CZ, SK, PL) is mainly related to the presence of highly sensitive secondary spruce forests and to direct or indirect effects of drought (SK, HU). The main factors causing high forest sensitivity in the Romanian and Serbian Carpathians are drought together with the related biotic damage, acting mostly upon broadleaved forests. High frequency of windstorms and subsequent bark beetle outbreaks are impact factors throughout the Carpathians. In Poland, low climatic exposure along with good forest structure and low biotic risk reduces vulnerability. The assessment stresses the importance of developing specific forestry measures in a trans-national context, to focus on mapping and designation, identification of refuges, cross-border linkages, and management measures such as thinning, fire management and invasive species management. Changes in forest management can be progressively implemented, e.g. after an extreme weather event or logging causing substantial forest loss. In the vicinity of villages in particular, action is recommended to reduce the impact of (illegal) logging on landslides, erosion and flash floods.

Recommended adaptation forests / forestry

- Promote (transnational) *sustainable forest management* enabling natural processes (concepts like close-to-nature-forestry, reduced clear-cutting, natural regeneration) and capitalising on the indispensable role of forests in water retention, erosion control and fresh water provisioning;Erosion control measures (close to villages) to reduce impact of (illegal) logging and flash floods;
- Increase the share of drought tolerant species, mainly of oaks, including Mediterranean species in exposed sites; reduction of vulnerable water demanding conifers, and beech in lower elevations;
- Support and harmonize regional and European forest monitoring schemes, including transboundary monitoring of newly emerging pests and pathogens;Promote risk rating in forest management rather than currently applied indicators of forest productivity;
- Avoid forest fragmentation and support connectivity of larger forest areas to support species natural migration and gene flows.

Vulnerability of agriculture

Due to changing precipitation, temperature and seasonality, agriculture will experience substantial pressures. Agriculture may become feasible at higher altitudes. In some parts of the Carpathians maize and wheat yields of the current varieties will decline, whilst elsewhere sunflower and soya yields might increase due to higher temperatures and migration of these crops' northern limit. 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 also 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 pastoralist -whom grasslands depend on for both their existence and the implementation of potential adaptation measure- 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 advancement of forest area, encouraged by climate change.

Recommended adaptation agriculture

- Support small-scale traditional farms as important economic activity delivering multiple ecosystem services;
- Agro-environment programmes are critical to maintain and enhance biodiversity and viability of semi-natural grasslands and mixed agro-ecosystems;
- Awareness campaigns on new climate resilient varieties and management techniques (e.g. climate smart agriculture).

Vulnerability of tourism

Tourism will experience both positive and negative impacts from climate change. Ecotourism, summer tourism, health tourism and vocational tourism can be positively influenced by climate change. Rising temperatures in summer both in the Carpathians and elsewhere, for example the Mediterranean, can bring more tourists to the mountains for comfortable temperatures. On the other hand, the possibilities of winter sport will become more limited. Projections of snow duration and depth indicate significant change for the coming 50 years. However, as tourism in the Carpathians is presently very diversified, only a small part of the visitors depend on the snow availability. Thus snow cover and snow depth changes will not have such a large impact on the entire tourism turnover as was formerly supposed. Besides, the profile of the old, winter sport-based resorts is changing and the majority of the tourists visit the hotels and pensions in the summer periods nowadays, meaning that tourism in higher mountains is already adapting to new conditions. It is estimated that climate change can bring 60-75,000 additional tourists per year with 9.6-12 million euro additional revenue for the region. A Southeast-Northwest gradient of vulnerability is reported, with the South-Carpathians' tourism the most vulnerable.

Recommended adaptation tourism

- Continue to invest in diversification of resorts and markets;
- Monitor changes in snow cover and communicate trends;
- Evaluate investments in tourism infrastructure (including such measures as artificial snow) in the light of projected water availability.

Strategic Agenda on adaptation to climate change

At a regional level, linking different policies of nature conservation, river basin management and sustainable farming, could significantly strengthen the Carpathian region and its resilience to climate change impacts. Regional cooperation platforms, like the Carpathian Convention, could be a critical vehicle to mainstream this in different countries. Countries in the Carpathian region can increase their resilience and tap into European resources by mapping out a path towards a climate-proof future which draws upon, and conserves, the unique natural and cultural values of the Carpathian region. The added value of increased transnational cooperation and joint activities is especially strong when planning for climate change adaptation, as much of the predicted impacts of climate change relate to seasonal and geographical shifts. This is true for species and communities (forests, tree-lines, northern limits) as well as for socio-economic aspects (tourist arrivals, tourism seasons). Many of the possible measures are thus best planned using a geographical scale of the eco-region, rather than the nation-state. Further, many of the tools and capacities required for climate change adaptation which are currently missing, such as the capacity for designation and mapping of future refuge habitats for wetlands and grasslands, are either only possible at the transnational level, or are equally missing in each country, meaning that joint initiatives could fill these gaps and build cooperative capacity at the same time. Financial resources are limited. A key action is to create flexible and equitable financial instruments that facilitate benefit - and burden- sharing, and that support a diverse set of potentially better-adapted new activities rather than compensate for climate impacts on existing activities. To succeed, new partnerships between government, civil society, the research and education institutions, the private sector and international organisations will be key. Essential components of such partnerships will be capacity building and knowledge sharing, climate-proofing of infrastructure and investments, climate-cross compliance, and design of eco-system based adaptation measures to make biodiversity management more dynamic.

1 Introduction

The CARPIVIA project (Carpathian integrated assessment of vulnerability to climate change and ecosystem-based adaptation measures) aimed to assess the vulnerability of the Carpathian region to climate change in combination with other anthropogenic pressures. It was funded by the European Commission and contributes to the preparatory action "Climate of the Carpathian Basin" approved by the European Parliament. CARPIVIA is implemented by Alterra, Wageningen UR, together with its partners ECNC, ECORYS, Grontmij and WWF-DCP.

The work undertaken under the 2010 allocation of the preparatory action "Climate of the Carpathian Basin" was organised in two closely interlinked contracts:

- The CARPIVIA project (lead partner: Alterra, Wageningen UR): a service contract for the integrated assessment of vulnerability of environmental resources and ecosystem-based adaptation measures (DG Environment service “The integrated assessment of vulnerability of environmental resources and ecosystem-based adaptation measures” (DG ENV.D.1/SER/2010/0048));
- The CarpathCC project (lead partner: Regional Environmental Center (REC)): a framework contract for in-depth assessments of vulnerability of environmental resources and ecosystem-based adaptation measures. These in-depth assessments correspond with knowledge gaps identified during the first year of the CARPIVIA project.

This document is the final report of the CARPIVIA project. It updates the interim assessment of the CARPIVIA project with the results of the in-depth assessments done by the CarpathCC project (Task 4.1 specified in the Terms of Reference for the CARPIVIA project [SPECIFICATIONS to Invitation to Tender DGENV.D.1/SER/2010/0048]). In addition this report builds on the results of the Climate of the Carpathian Region project (CARPATCLIM) led by the Hungarian Meteorological Service which looked at historic climate data from 1961-2010 and produced a high resolution database for the Larger Carpathian Region which is available at http://www.carpatclim-eu.org.

Thus this final report reports on the vulnerability, impacts, potential adaptation measures that have been identified following the CARPIVIA Vulnerability Framework enhanced with the findings of the CarpathCC project. Chapter 2 contains a brief summary of the methodology. In Chapter 3 the main climate threats are summarised. Chapter 4-6 report on the impacts of climate change on water resources, ecosystems and ecosystems based production systems respectively. Next, Chapter 7 reports on potential adaptation measures. Chapter 8 reports on stakeholder involvement. Chapter 9 offers a strategic agenda for adaptation to climate change in the Carpathian Region. And finally Chapter 10 presents the Metadata catalogue and information system.

Results of the CARPATCLIM, the CarpathCC and the CARPIVIA project have also been made available in a summary booklet, available from: http://www.grida.no/ publications/e-book.aspx?id=6205&url=grid.cld.bz/FutureImperfect

2 Methodology / Vulnerability Framework

This project makes vulnerability operational in a number of practical steps. In particular, the vulnerability framework consists of two main components:

1. Defining a number of process steps for the vulnerability assessment that link the various tasks in the project, including the interaction with clients and stakeholders of the assessment.
2. Framing the vulnerability assessment by scoping the main elements of the assessment (Vulnerability framework).

Below these two components are introduced in more detail.

2.1 Process steps of the vulnerability assessment

The process steps are illustrated in Figure 2-1. The figure shows how vulnerability is made operational in four main steps:

- *Step 0:* the vulnerability assessment is scoped (see also Section 2.2)
- *Step 1:* potential impacts are assessed in an impact assessment (also called, preliminary vulnerability assessment). The assessment of impacts includes:
  - The description of the affected systems & a long list of possible consequences of climate change for a region or sectors
  - Prioritisation of climate change trends and impacts
  - Analysis of policy objectives / standards / administrative arrangements, Public opinion, and/or Statistics to determine what impacts and rates of change are problematic

  From the assessment: Impacts were either included in the interim project report, or -if no information is available- listed as missing information for the gap analysis (CarpathCC).
- *Step 2:* potential adaptation measures are identified and assessed, focussing on adaptive water management and ecosystem based-approaches. The impacts identified guide the selection of measures. This assessment also informs the gap analysis.
- *Step3:* the impact assessment and the adaptation assessment along with the results from the supporting studies carried out under the framework contract are combined in a integral vulnerability assessment.

It is important to realise that the steps listed above will be implemented partly in parallel, to ensure optimal feedback and iteration between the different steps in the vulnerability assessment. Step 0-2 have been reported on in the CARPIVIA Interim report. The present document reports on Step 3.

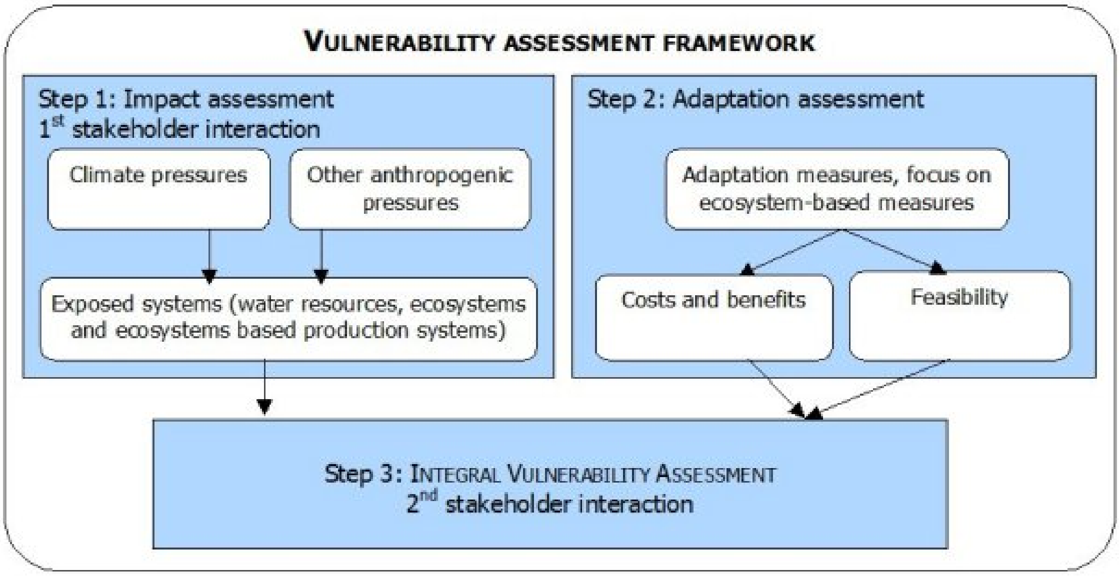

Figure 2-1 *Vulnerability assessment framework (Task numbers refer to Tasks in the Terms of Reference).*

2.2 Scoping our work / summary vulnerability framework

Table 2-1

Summary Vulnerability Framework.

	Integral vulnerability assessment	
	Impact assessment (first order vulnerability assessment)	**Adaptation assessment**
Goal / objective	Identify available information on impacts & knowledge gaps. In addition: • *To raise awareness of causes vulnerability* • *To inform plans & decisions to reduce vulnerability* • *To identify focal areas for further detailed analysis*	To identify and discuss the costs, benefits and feasibility of potential adaptation measures that serve to reduce vulnerability. To contribute to on-going national or regional adaptation strategies or related policy processes, like the Commission White Paper on Adapting to Climate Change, National or Regional adaptation strategies, a Danube Climate Adaptation Strategy, EU Knowledge Base on Climate Vulnerability and Adaptation.
Client	European Commission, UNECE, JRC, EEA, ICPDR, the Secretariat of the Framework Convention on the Protection and Sustainable Development of the Carpathians, National and regional authorities of the Carpathian Region. Focus will be on the Carpathian Convention & national authorities as key user group, in particular the new working group on adaptation under the convention	
Stakeholders	Representatives from water, navigation, agriculture, tourism and energy sector. Next to NGO's and national, regional local authorities, S4C Network, CERI, participation of private sector	
Conceptual frame	The concept of vulnerability will be made operational in view of the particular purpose of a project's vulnerability assessment. It will consist of a stepwise process. Potential impacts will be assessed by making explicit: (1) what exposed systems are considered, (2) the threats or pressures to which these systems are exposed and (3) what indicators are used to evaluate the impact of the threat on the exposed system. In other words to be explicit about: who or what is vulnerable, to what, and with respect to what?	The identification of potential adaptation measures consist of a stepwise process: - 1) A long-list of measures is prepared with focus on adaptive water management and ecosystem based-approaches - 2) Based on expert judgement the long-list is reduced to a short list with most promising measures for forestry, wetlands, grassland, agriculture and water - 3) Selected measures are appraised

	Integral vulnerability assessment	
	Impact assessment (first order vulnerability assessment)	
Scales / boundaries system	Differentiated approach with focus on the mountainous area (search area Carpathian Convention). Link geographical extent to the types of drivers (e.g. flash floods in the mountains). The Danube is not included (e.g. navigation issues on Danube). Effectiveness of measures extends into the Pannonian plain. Differentiated geographical boundaries: • Present climate data for larger area, including Pannonian plain and adjacent areas • Assess vulnerability of different ecosystems for study area of Carpathian convention • Discuss adaptation option for a number of reference areas (e.g. target river basins) • Consider all countries as mentioned in ToR for policy and actor involvement.	Measures currently implemented within the project area or within areas with similar vulnerability. Since the Terms of Reference asks for emphasis to be given to adaptation of water and ecosystems to climate change and other human induced pressures it is proposed to focus on a number of focal areas and adaptation options which are representative for the main vulnerabilities of concern in the Carpathian region
Exposed systems	Ecosystems [classified at different levels of detail] Ecosystem based production systems, services and sectors (agriculture, forestry, energy, tourism) Water resources	
Indicator selection[1] Link to policy objectives Link to policy objectives	Focus on the selection of pressure and exposed system specific indicators, rather than indicator aggregation. Other considerations for indicators selection include that they i) can be assessed easily and at a reasonable cost; ii) are policy relevant, clear and informative for resource managers, decision-makers and the general public; iii) reflect the interests, concerns and values of the local population and express major regional issues.	The costs of measures will be expressed in monetary terms and as far as possible in unit costs. The benefits will be described qualitatively and presented in such a way that the different measures can be easily compared to each other. Full monetisation of the benefits is not possible, since the benefits of the measures differ case by case.
Presentation / communication of results	Reports. Stakeholder meeting in close cooperation with Carpathian Convention. Presentations and a dedicated website. Summary booklet	
Stakeholder interaction	Two major interactions and up to 10 presentations of results. Objectives are to inform potential users about outcomes and prioritise impacts for further study.	Involve in assessment of feasibility and prioritisation of adaptation options for further study.

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[1] The vulnerability assessment and indicator selection will take into account the results of recent Guidance documents and workshops, such as the Guidance of UNECE and the Workshop on Climate Vulnerability Indicators, at DG Environment on June 18 in Brussels. In addition, indicator selection will be informed by various past and ongoing projects such as the Aquastress, the ClimateAdapt and the SCENES project.

3 Key climate change pressures

This chapter summarises pan-Carpathian historical climate trends and projections for the coming century. It focuses on temperature and precipitation. This chapter only indicates the main trends. Support maps and additional scenario information are available through the CARPIVIA website, the CarpathCC reports and the CARPATCLIM project in particular. For the knowledge base disclosed, CARPIVIA consulted and built on the European Climate-Adapt site. In addition cooperation was sought with the inventory made for the Danube Adaptation strategy and with the Alpine Convention.

3.1 Past climate change in the Carpathian region

The Carpathians are a long, relatively low mountain chain with a complex topography. The highest peak is 2655 m. The mountain range is strongly curved, which causes a diverse atmospheric climate and makes the climate inside the mountains different from the areas outside. The region was well developed even during the Middle Ages, thus more documents are available providing proxy climate data for this region than usual. Historic climate trends are mapped on the basis of instrumental measurements and proxy data (paleobotany, paleozoology, dendrochronology, isotope measurements and documents) (Brazdil *et al*. 2005). An increasing annual mean temperature trend for the whole Carpathians has been identified, yet with strong spatial and temporal variations. Seasonal trends are different, significantly increasing temperature was identified for the summer period and for the two intermediate seasons, while winter temperature shows a more complex varying picture with no significant average temperature increase. Figure 3-1 and Figure 3-2 illustrate the typical pattern of increased mean temperature and precipitation for an 11 year time series. Figure 3-2 also illustrates the strong natural variability inherent to precipitation if compared to temperature.

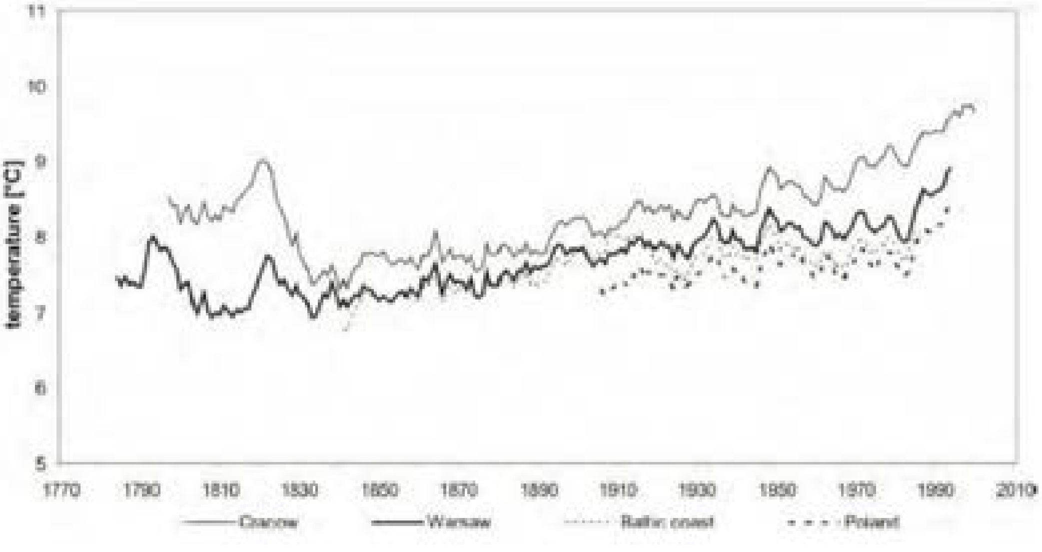


Figure 3-1 *11-year running mean annual air temperature in Poland (Przybylak 2011).*

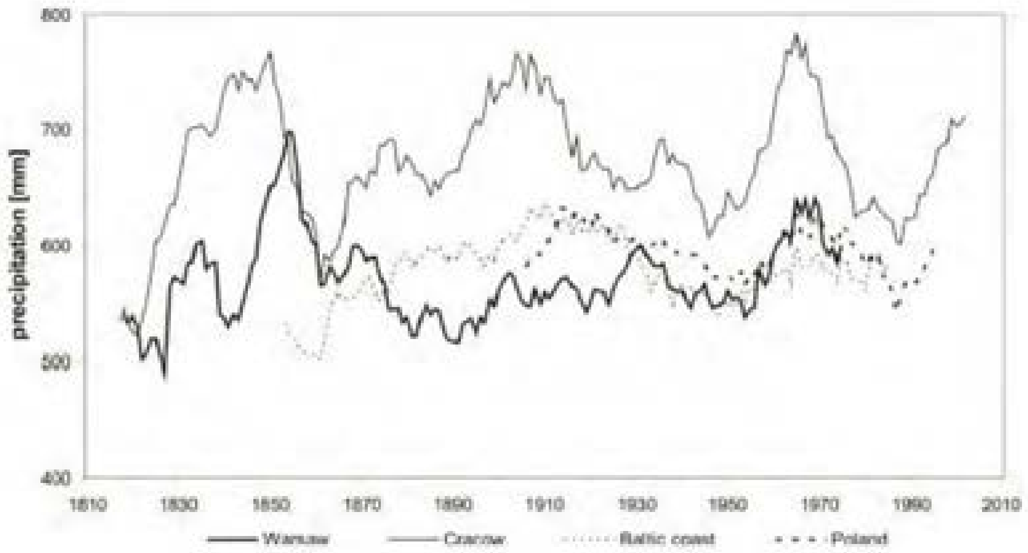


Figure 3-2 11-year running mean annual precipitation in Poland (Przybylak 2011).

The CARPATCLIM study of the last 50 years show similar trends to the ones illustrated above (Szalai, 2012). The temperature changes have a clear geographical distribution, with decreasing temperatures from west to east and from lower altitudes to higher (Figure 3-3). The characteristic values change between 0.6 and 1.65°C, with the lower values in the Romanian Carpathians and the higher values in the west of Slovakia. This difference is mainly due to the winter temperature changes. The summer temperature changes shows an even spatial distribution, meaning that the temperature increase is the same or very similar for the entire Carpathians. The winter values show a more varied picture with decreasing temperature in the Eastern and Southern part of the Carpathians, while the Northern and western part show a slight increase (Figure 3-4).

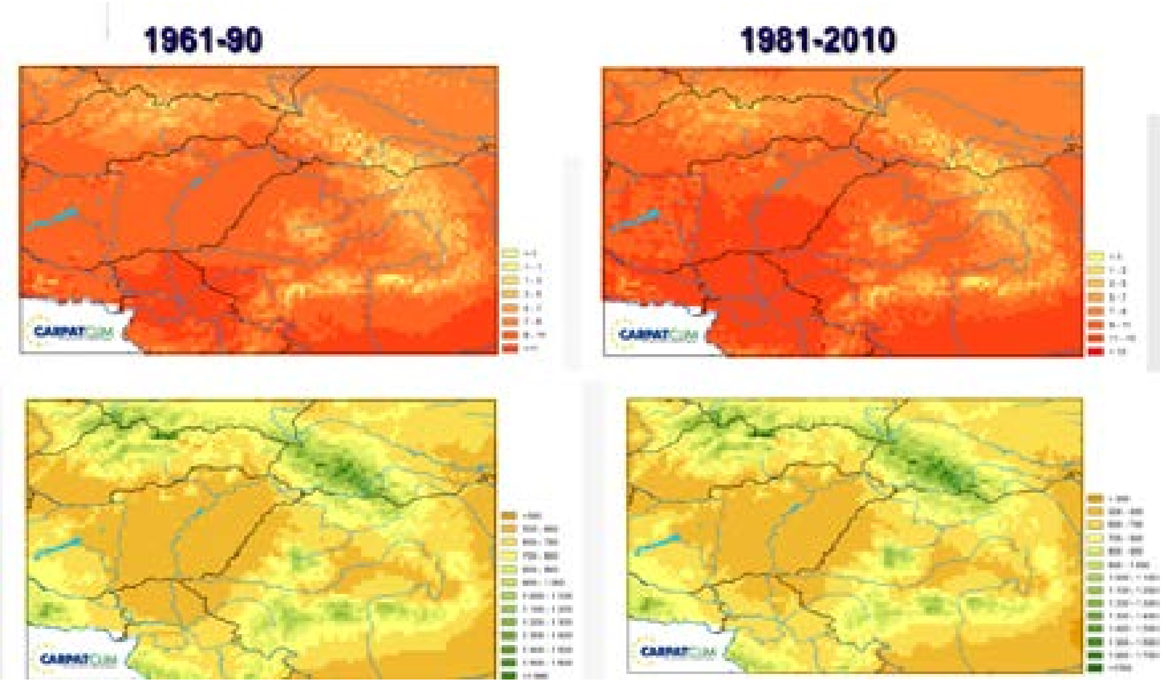


Figure 3-3 Mean annual temperature (upper row) and annual precipitation (lower row) for the period 1961-1990 (left) and 1981-2010 (right).

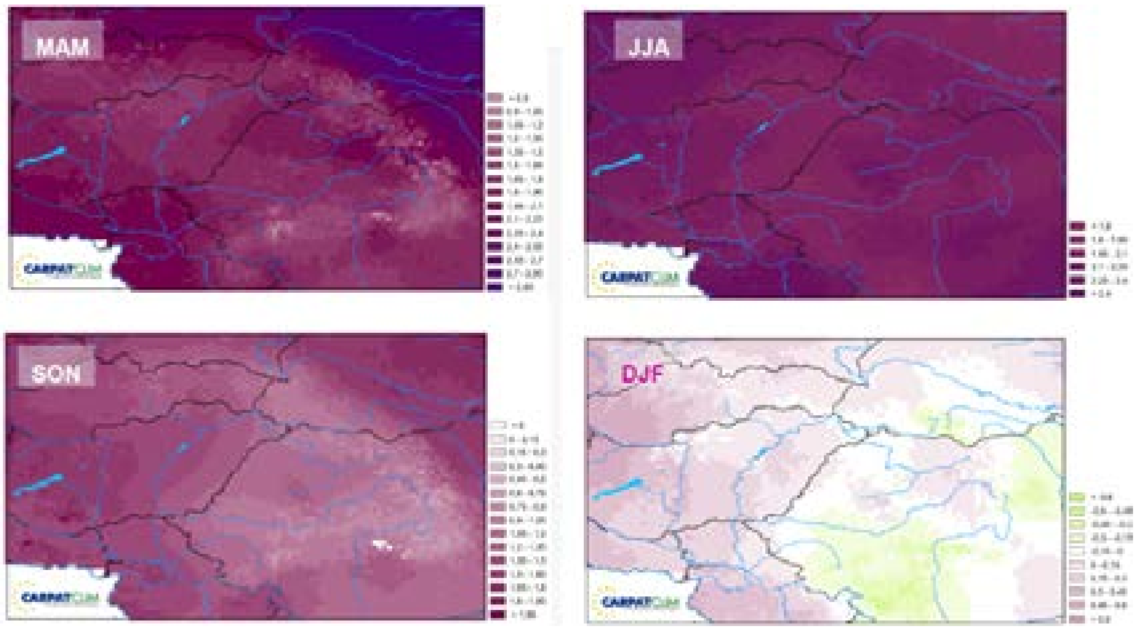


Figure 3-4 *Seasonal temperature changes, 1961-1990 minus 1981-2010 (spring upper left, summer upper right, autumn lower left, winter lower right).*

The spatial distribution of the precipitation changes is also heterogeneous. The North and North-eastern Carpathians experienced an increase up to 300 mm, while the Western and South-eastern part faced a decrease of 100-150 mm (Figure 3-5). The seasonal changes show even greater spatial differences (Figure 3-6). On average, the two intermediate seasons show more decreasing tendencies, while winter and summer show more increasing tendencies, with large spatial variability. Comparing observations and model trends, differences can be detected, especially in summer. Models show a summer drying trend, which is not yet strongly supported by observations. Observations support a W-E drying gradient, while climate model results suggest a S-N (SW-NE) gradient rather.

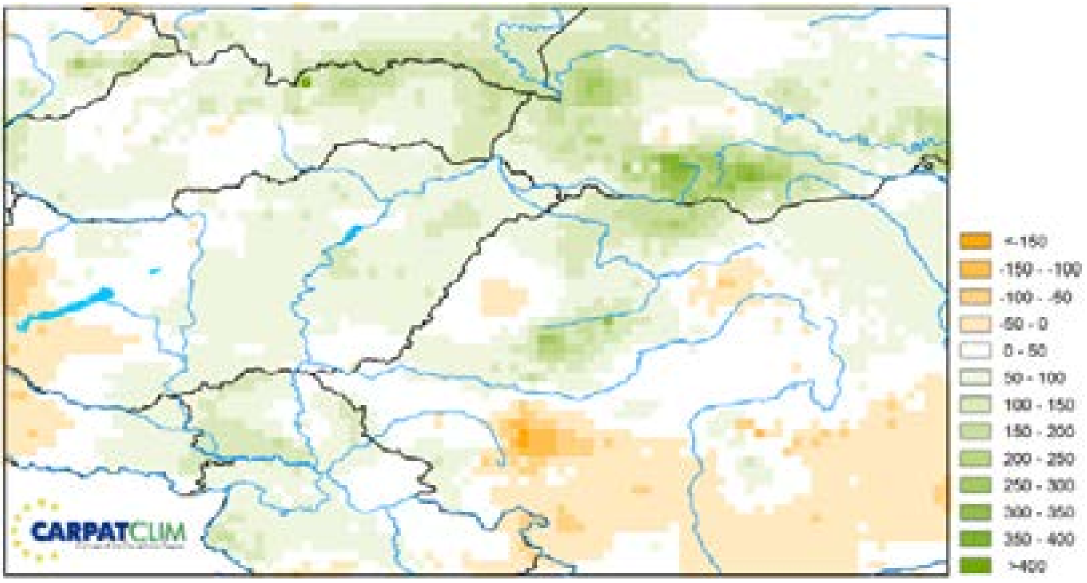


Figure 3-5 *Change in annual precipitation 1961-1990 minus 1981-2010 (Source: CARPATClim Project).*

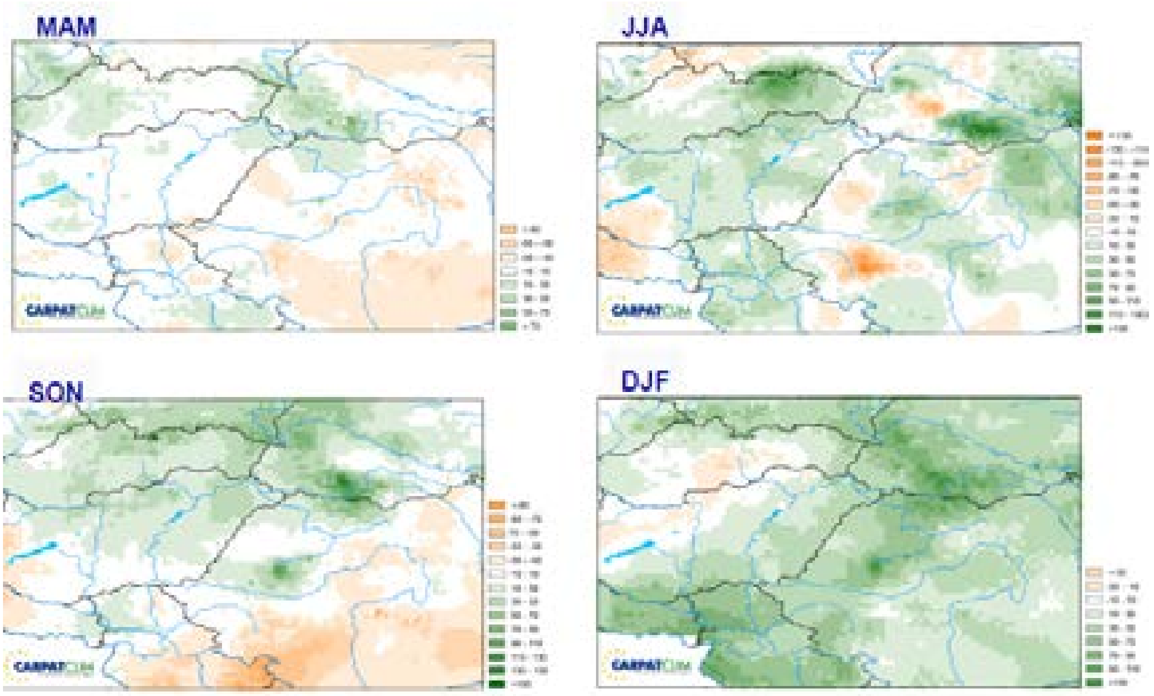


Figure 3-6 *Change in seasonal precipitation 1961-1990 minus 1981-2010 (spring upper left, summer upper right, autumn lower left, winter lower right).*

With respect to more extreme events, the number of hot days is increasing, whereas extreme cold temperature values are decreasing. Winter days decrease everywhere in the Carpathian region, with very few exemptions. A robust decreasing can be seen in the Northwest Carpathians (-18–-20 days). In South and East Carpathian small increases can appear. The changes of the number of hot days are in strong correspondence with the topography. The increase is less at higher mountains than at lower altitudes. More hot days occur in the basin, especially in the territory between Danube and Tisza rivers, by 18 –22 days from 1961 to 2010. The Transylvanian basin shows fewer rises. The region under the South and East Carpathians showed the largest increase in number of hot days (over 24) between 1961-2010. In addition, the change in the number of days with precipitation above 20 mm is positive almost everywhere.

Summarising, the present climate in the greater Carpathian region shows high spatial variability, and sometimes tendencies that are opposite to the general theories used in climate models. This underlines the importance of the cautious management of climate change measures, since general statements may not be valid for smaller localities in the Carpathians.

3.2 Climate change projections

3.2.1.1 Temperature and Precipitation

Climate change projections suggest more irregular rainfall and a warmer climate in the Carpathian basin (Láng, 2006; Bartholy *et al.*, 2007). Studies of temperature change over the Carpathian Basin largely agree in projecting an increase in future temperature. The Carpathian mountains are projected to experience an increase between 3.0 ºC in the north-western part to 4.5ºC in the south towards the end of the century.

The projected trends in temperature and precipitation are illustrated in Figure 3-7. The different colours represent different global-regional climate model (GCM-RCM) combinations from the ENSEMBLES project, and illustrate model uncertainty. The figure shows results for one possible greenhouse gas emissions scenario (the A1B Scenario).

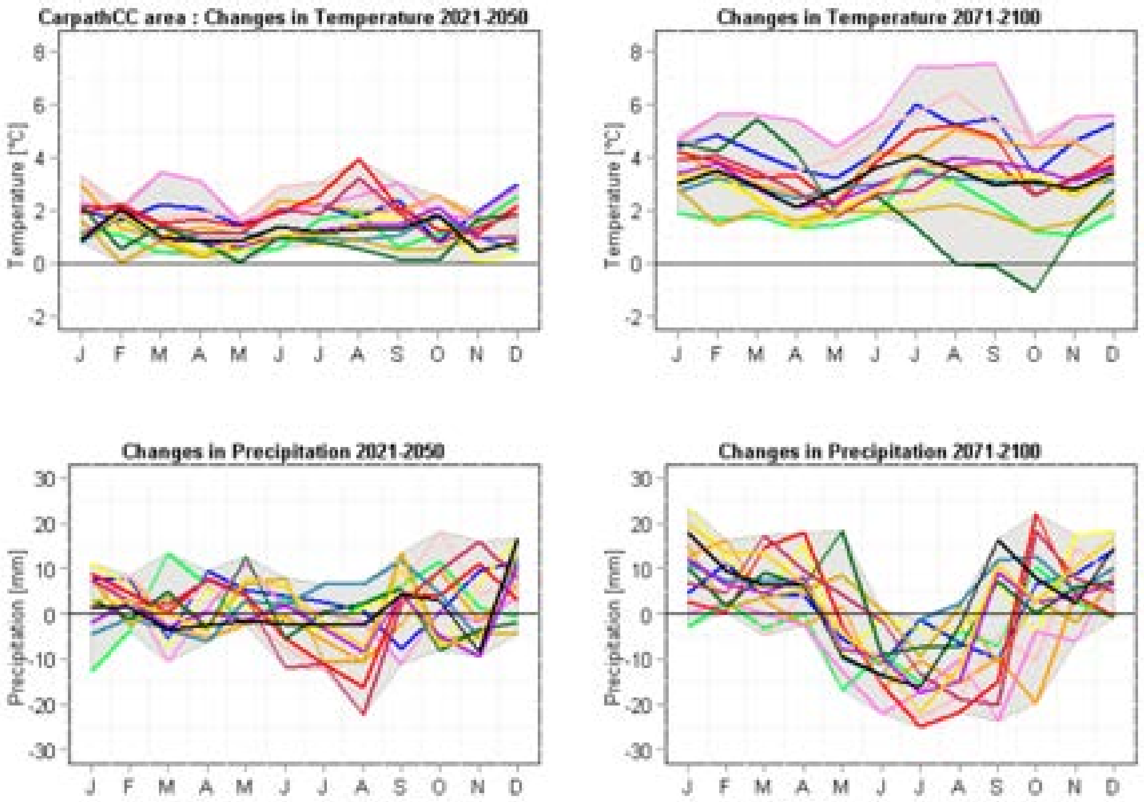


Figure 3-7 *Changes in air temperature (top) and precipitation (bottom) for the future periods 2021–2050 (left) and 2071–2100 (right), compared to the reference period (1971–2000).*

Figure 3-8 maps the mean seasonal temperature and precipitation change for the A1B greenhouse gas emission scenario. In summary, increasing annual average temperatures are expected throughout the Carpathians with higher increase in the SE and lower in the NW 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 NW 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 increases in winter precipitation in most areas of between 5 to 15%.

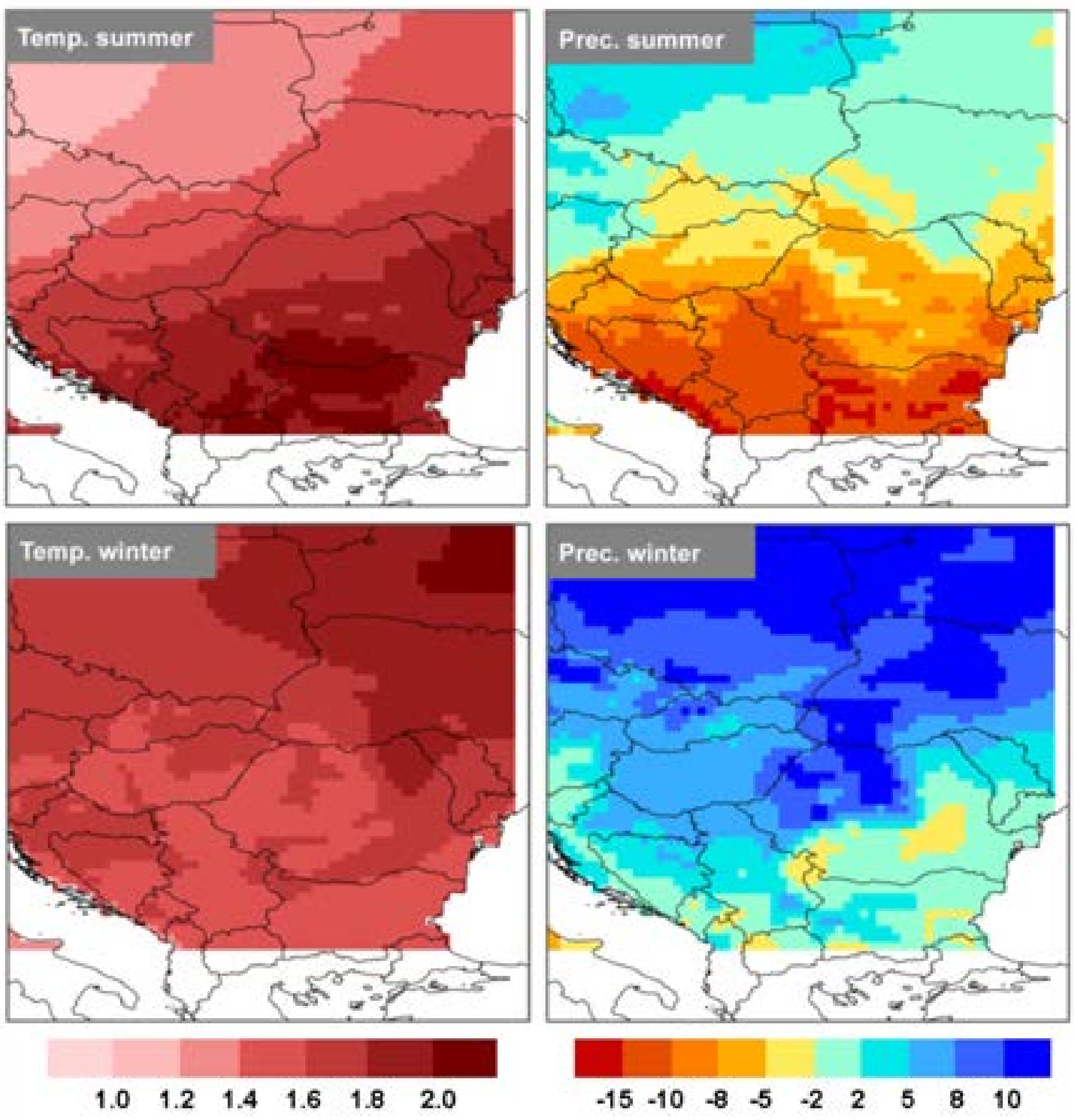


Figure 3-8 *Changes in daily mean air temperature (°C) (left) and precipitation (%) (right) in the greater Carpathian region in winter (DJF) and summer (JJA) as the multi-model mean for the years 2021–2050 relative to 1971–2000 (absolute differences in mm), for the A1B greenhouse gas emissions scenario with 14 different GCM-RCM combinations from the ENSEMBLES project.*

Table 3-1 illustrates these large and opposite trends for different seasons, implying that the annual distribution of precipitation can be restructured. The wettest summer season may become the driest (especially in case of A2 scenario), and the driest winter is expected to be the wettest by the end of the 21st century.

Table 3-1

Expected mean precipitation change by 2071-2100 for Hungary using 16 and 8 RCM simulations for scenario A2 and B2, respectively (Bartholy et al., 2007).

Scenario	Spring (MAM)	Summer (JJA)	Autumn (SON)	Winter (DJF)
A2	0 – (+10)%	(-24) – (-33)%	(-3) – (-10)%	(+23) – (+37)%
B2	(+3) – (+12)%	(-10) – (-20)%	(-5) – 0%	(+20) – (+27)%

3.2.1.2 Meteorological drought events

Drought is a natural phenomenon that is usually caused by lack of precipitation over a sustained period of time. It is one of the most important climate-related natural hazards. With respect to future climate change adaptation, it is important to know how drought conditions might change in the Carpathian region. Droughts can be classified as meteorological, hydrological and agricultural droughts (Livada and Assimakopoulos 2006). This section pays specific attention to *meteorological* drought occurrence.

Meteorological droughts can be described using drought indices. According to the national meteorological and hydrological services (NMHSs), the standardised precipitation index (SPI) is one of the most reliable indices and should be used to characterise meteorological droughts (Hayes *et al.* 2011). The SPI is defined as the difference in precipitation from the mean for a specified time period divided by the standard deviation, where the mean and standard deviation are determined from past records (McKee *et al.* 1993). In the SR1 study (CarpathCC, http://carpathcc.eu/node/35) the SPI was used to analyse drought events in the Carpathian region and to provide drought forecasts in the context of future climate change. The CLAVIER database was used to calculate the SPI values. The results are summarized below. Here droughts are classified by severity (i.e. moderate, severe and extreme) and duration (i.e. short: 3 months and long: 12 months).

Moderate drought events.

Moderate drought are characterized by an SPI of < -1. In the Carpathian region as a whole, the probability of moderate drought events was far lower in the period 1971–2000 than expected for the period 2010–2050. Figure 3-9 presents the spatial distribution of the calculated probability of short-term (3-month) moderate drought events. The majority of the areas with the risk of moderate drought events are in the central part of the Southwestern Carpathian sub-region, including the Iron Gates National Park (NP), and the eastern side of the Southern Carpathians, including the Tarnave Mare area. In the southern part of the Northwestern Carpathians (around Budapest), the probability of drought events is also expected to increase. The least affected areas are expected to be the Rodna-Maramures area and the eastern borders of the Northwestern Carpathians.

Severe drought events

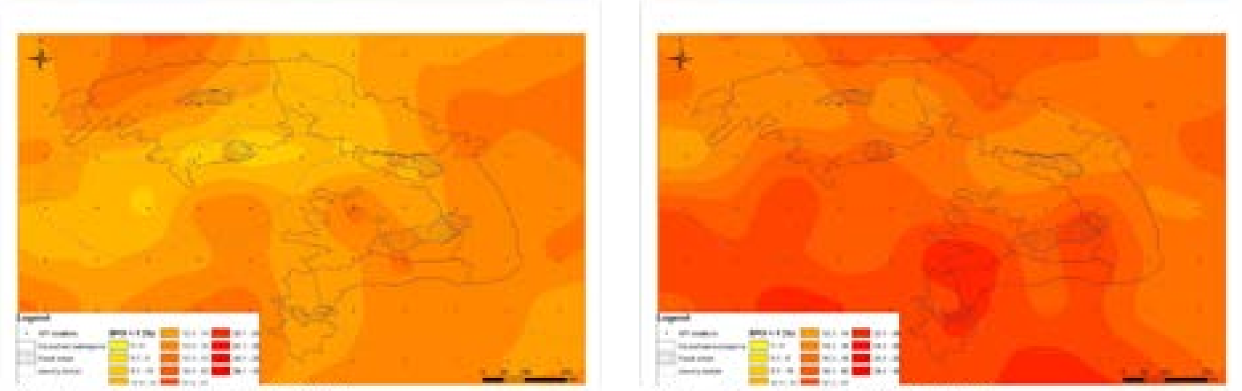
The probability of severe drought conditions is expected to increase in the Carpathian region in the 2021–2050 period. In fact, the change is more pronounced than for moderate droughts. The most affected areas are similar: the Southwestern Carpathian sub-region north of the Iron Gates NP and the eastern side of the Southern Carpathians, including the Tarnave Mare area. The probability of long-term (12-month) severe drought events may also be relatively high in the Northwestern Carpathian sub-region, at the western border of the Bükk Mountains and in the Rodna-Maramures area. The areas least affected by severe droughts are expected to be the Tatra Mountains and the Northeastern Carpathian sub-region.

Extreme drought events.

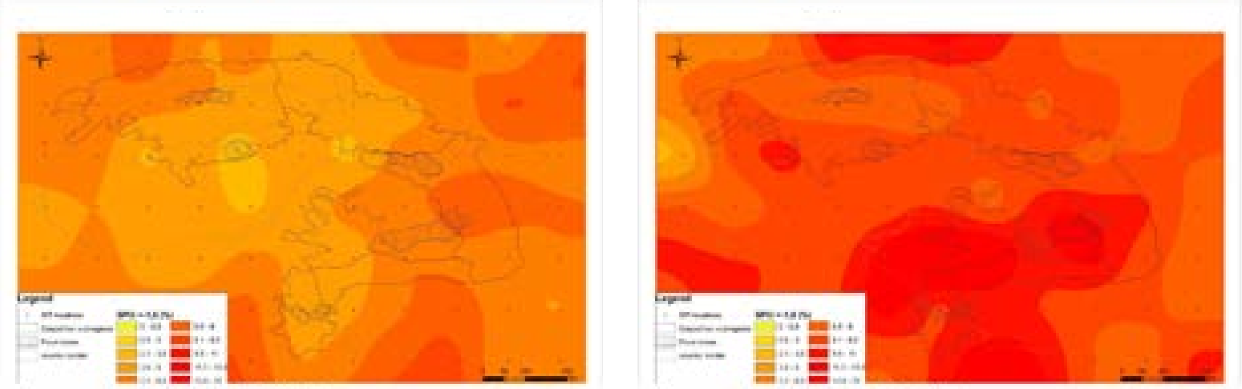
The biggest change is in the probability of the occurrence of drought events is found for extreme droughts. While the increase in the probability was around three and a half for moderate droughts and around five times for severe droughts, the probability of extreme droughts are found to increase around seven fold. The most affected areas are the region between the Bükk Mountains and the northern part of the Southwestern Carpathian sub-region, and the Tarnave Mare area. The probability of long-term (12-month) extreme drought events is high in the Eastern Carpathian sub-region and in the eastern half of the Rodna-Maramures area. The areas least likely to be affected by extreme droughts are the Tatra Mountains and the Northeastern Carpathian sub-region; and the area least likely to be affected by long-term drought events is the Iron Gates National Park.

Based on this study, it can be concluded that both the frequency and severity of drought events are expected to increase in the whole Carpathian region. The regional differences of the projected distribution and severity of the drought events are substantial. Long-term drought events are expected to occur mainly within the Carpathian basis, especially in the case of extreme drought. The areas most affected by droughts are the Southwestern Carpathian sub-region, the Southern

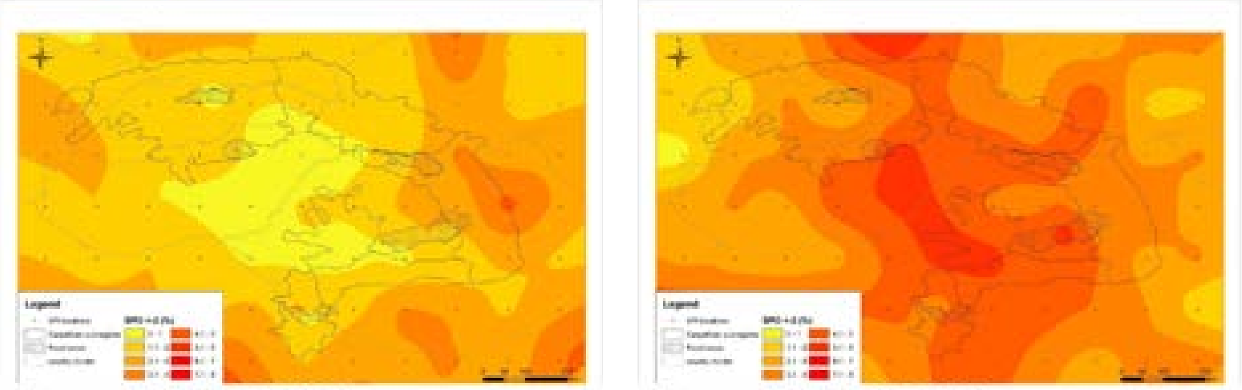
Carpathian sub-region and the Tarnava Mare region. The areas least affected are the Tatra Mountains, the Rodna-Maramures and the Northeastern Carpathian sub-region.



Moderate drought 1971-2000 Moderate drought 2021-2050



Severe drought 1971-2000 Severe drought 2021-2050



Extreme drought 1971-2000 Extreme drought 2021-2050

Figure 3-9 *Probability of short-term (3-month), moderate, severe and extreme drought events (%) in 1971–2000 (left) and 2021–2050 (right).*

4 Water resources: impacts of climate change threats, adaptation & vulnerability

4.1 Current status

This chapter focuses on implications of climate change for water resources. River flow and (fresh) water availability in rivers, lakes and groundwater have changed substantially over the last decades (Ludwig *et al.*, 2009). Groundwater tables have declined several meters and already cause economic damage in agricultural areas that are susceptible to aridification (Rakonczai, 2011).

Rivers

The three largest river basins in the Carpathians region are the Danube, Dniester and Vistula basin. Generally, river valleys in the Carpathian region have a small retention capacity, causing violent surface runoff during heavy rainfall, resulting in sudden and prolonged increase in water level in rivers and streams. The Danube and Tis(z)a valleys are very prone to frequent flooding. Also, the Dniester has a specific flow regime with up to five flooding events per year. In 2005 floods killed 34 people, displaced 2,000 people, inundated 690 km2 and caused USD$625 million (€396 M) in damages in Hungary, Romania, Bulgaria and Moldova. A year later a flood displaced 17,000 people, inundated 1,450 km2 and cost USD$8.6 million (€5.5 M) in Romania. Part of these changes are due to a different climate, but other factors like increasing water use, abstractions, urbanization and deforestation can also have a major impact upon water flow and availability and determine the vulnerability of the water resources to climate change. The Danube and its tributaries are especially under pressure by impoundments (barriers / hydropower dams) and water abstractions. About half of the water bodies are affected by hydrological alterations such that the remaining flow below the water abstraction or dam is too small to ensure the existence and development of self-sustaining aquatic populations and hinders the achievement of environmental objectives (ICPDR, 2009).

The Dniester has a specific flow regime with up to five flooding events per year. Many towns and cities are situated along river banks, making them highly vulnerable for flooding events. In the river basin of Vistula, water resources supply industry, agriculture and municipal waterworks. However, due to insufficient waste water treatment from industry, urban areas and arable lands, water quality is strained. The Danube river basin also struggles with low water quality and eutrophication due to unsustainable agricultural practices, lack of municipal water treatment and industrial waste. Some river basins also suffer from pollution through heavy metals due to mining activities. Still, there are many water bodies which are isolated from anthropogenic pressures and are in good state with high ecological value. These are usually situated in higher mountainous areas.

Lakes

The Neusiedler lake is by far the biggest lake in the Carpathian region (315 km2). It is situated in the foothills and a very shallow lake (depth < 2 m). Its shallowness results in a unique ecosystem but also makes the lake vulnerable for changes in the water level. Furthermore, there are about 450 small lakes in the mountain part of the Carpathian region (total surface 4 km^2), most of them postglacial.

Groundwater

Groundwater is by far the main source for human water consumption in the Carpathian region. Over 80% of the consumption is extracted from porous and karstic aquifers and due to the good quality these groundwater resources provide a basis for the mineral water production industry. At present, over abstraction in two of the 11 transboundary groundwater bodies in the Danube River Basin District of basin-wide importance (7-RO-RS-HU and 11-SK-HU) prevent the achievement of good quantitative status (ICPDR, 2009).

Soil water retention plays an important role in the hydrological cycle. Optimal water retention in the soil diminishes the impacts of extreme wet and dry weather conditions. In dry periods, soil water is still available for plant uptake and optimal infiltration and retention capacity diminishes the risks for flooding and landslides. The hydrophysical properties of soil determine the behaviour of water in the soil. In general soil management (tillage, changes in crops / land use) and urbanization has a more direct and probably bigger impact on these properties than climate change.

4.2 Main impacts of climate change on water resources

4.2.1 Overview

The main impacts of climate change on the water resources in the Carpathians are the result of changes in temperature and precipitation patterns and a higher inter-annual variability (See Chapter 3). These seasonable changes will affect water availability and water quality. Due to these changes, snow cover and glacier storage will decline and runoff regimes altered, with an increase in flooding events and possibly landslides. In their turn, these events increase the load of pollutants of receiving water bodies downstream and therefore affect the water quality. Runoff is expected to decrease in central and eastern Europe, while groundwater recharge is likely to be reduced, with greater reduction occurring in valley and lowlands. Dry summers will put ecosystem services like for instance drinking water at risk, resulting in water shortages. This will have its impact on economic sectors such as households, agriculture, energy production, forestry, tourism and, alternatively, river navigation. These shortages may create tension and conflict among users.

Direct impact on fresh water resources are often described in terms of drought, floods, recharge and storage in groundwater and snow/glaciers (IMGW, 2007; Tomasz *et al.*, 2007; CEU, 2008; EEA, 2009; Ludwig *et al.*, 2009). These changes impact rivers, lakes and groundwater and springs in terms of flow, water tables and water quality including temperature and health related quality problems. Table 4-1 gives an overview of the expected impacts.

Projections are available on future water quantity at the European scale and for major river basins. Except for the global scale projections, future water quantity was studied at the European scale by projects such as SCENES, PESETA, CLAVIER, and KLIWAS. River discharge studies include projections for the Danube (WATCH Project, see BOX 4-1), based on European or global scale models. The WATCH project has looked at the changes of water quality in the Danube River, as well as discharge levels over the next 100 years. Few climatological and water resources maps for the whole Carpathian region are available, especially at intermediary and high-resolution scale. Here the CarpathCC project has started to fill some of the gaps.

Table 4-2

Overview of the expected impacts on water resources.

Direct effects	Effects on fresh water resources		
	Rivers	Lakes	Groundwater
Water scarcity and drought	Decreasing water flows Low water tables temperature Impaired water quality (higher temperature, less dilution, eutrophication in slow flowing rivers) Salt water intrusion	Lowering water tables Disconnection of streams and other lakes Increasing temperature Impaired water quality (eutrophication, higher concentration of pollutants, health related problems)	Less recharge Changes in groundwater quality Indirect: more abstractions (drinking water, agriculture)
Floods	More flooding Increasing water flows Higher water levels and (more often) exceeding warning levels More diffuse pollution (nutrients, toxic chemicals, pathogens) Increased erosion and sediment transport	More periods with (extreme) high water tables Increased diffuse pollutions and related health problems	Infiltration surface water (more floods) More surface runoff and subsequent less recharge Changes in groundwater quality
Snow cover	Water flow; changes in seasonal patterns Increasing temperature of rivers (upper Danube) Impaired water quality (less snow melt)	Water tables; changes in seasonal patterns Increasing temperature (lakes fed by snowmelt) Impaired water quality (less snow melt)	Recharge (changes in seasonal patterns)

BOX 4-1: Future changes in the Danube Basin (WATCH Project)

For the Danube catchment, the five GCMs used in the WATCH project agree well in the direction of changes in the annual mean precipitation. The multi-model ensemble mean predicts a reduction of about 10%. Seasonally, the changes are bigger. All GCMs except BCCR (+4%) project a reduction in evapotranspiration yielding a –4% reduction in the multi-model mean. The changes in precipitation and evapotranspiration add up together in the change in runoff. In general the five GCMs agree in projecting a runoff decrease over the Danube (-24%). For the SRES scenarios B1 and A1B the projected changes are similar to the projected A2 changes.

Figure 4-1 show the projected monthly mean changes in temperature and the hydrological fluxes for the catchments of the Danube. For the Danube, CNRM and MPIM project a reduced runoff also during the winter while UKMO and BCCR project a winter increase, which is even relatively large for BCCR.

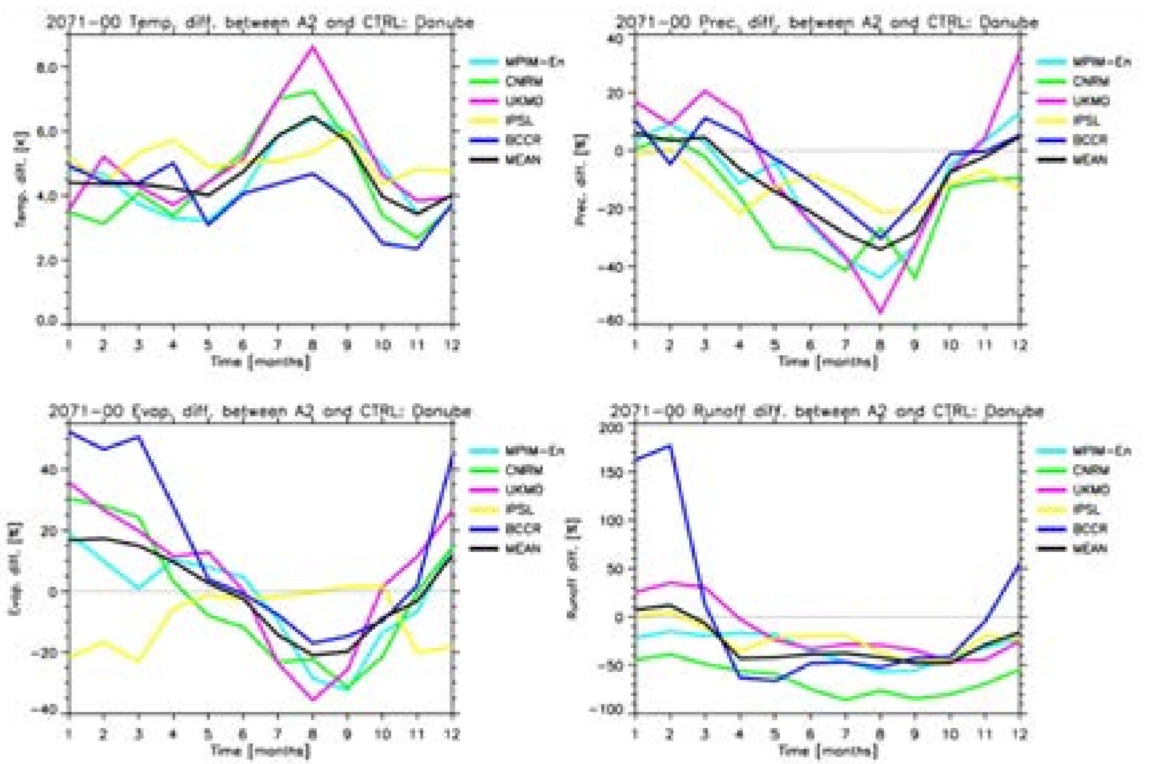


Figure 4-10 *Monthly mean changes of a) temperature, b) precipitation, c) evapotranspiration, and d) runoff over the Danube catchment for the A2 scenario in 2071-2100 compared to 1961-90. Source: (Hagemann et al., 2008).*

4.2.2 Impacts on rivers

According to model-based projections, water resources of Carpathian rivers are typically expected to increase in the winter half-year and decrease in the summer half-year as a result of climate change (see Figure 4-2).

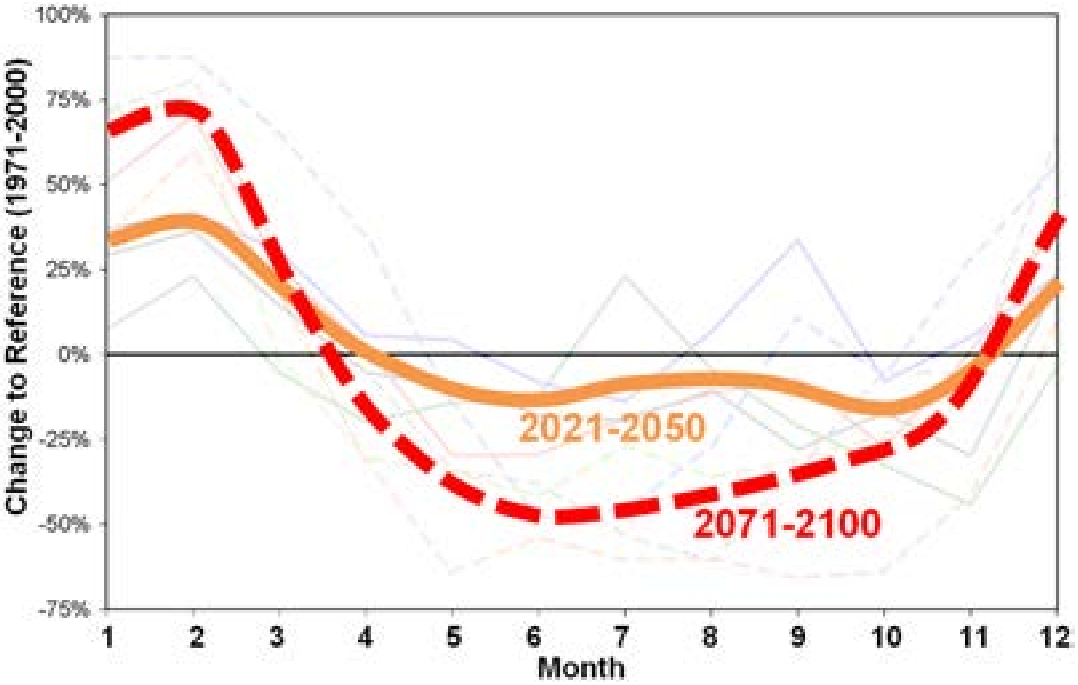


Figure 4-11 *Expected changes in monthly mean discharges of a large Carpathian river (Mures) – averaging of climatic scenario-based hydrological model projections.*

4.2.2.1 Floods / High flow events

High flow events have impacts on the river. Due to increase of water flow and water level, erosion of the river banks is very likely. This also applies to existing dikes and other flood protection measures. An overall increase in winter flow was detected in future projections and a rising tendency (although not always significant) towards flood extremes was also noted (Albert *et al.*, 2013). Most studies indicate an increase in flash floods, due to increase in winter precipitation and altering snow storage. Furthermore, anthropogenic contributions like overgrown river flow channel, regulation of rivers and land use also has its impact on future flood events. Due to increased water velocities, the river channels may erode and become damaged along with any flora and fauna within the channels. This results in increased sediment load which affects water quality in the rivers and its receiving waters (lakes and sea). With respect to water quality, increased flash floods events will lead to (more) uncontrolled discharges from urban areas and increasing storm events, especially a storm after a long period of drought, will flush more nutrients from urban and rural areas (Whitehead *et al.*, 2009).

4.2.2.2 Low flow events

In general, low flow and drought periods as well as water scarcity events are expected to increase. Regional studies point at periods of low precipitation resulting in lower summer river flow (e.g. Mic *et al.*, 2010). In the southern and eastern parts of the Danube river basin a decrease in runoff is projected, while in the northern and western parts no clear trend or even an increase in runoff is projected until 2050. It is projected that low flow and droughts will become more severe in summer and the periods of low flow, drought and water scarcity will be longer, while in winter they will become less severe. In particular, southern parts of Hungary and Romania as well as the Republic of Serbia, Bulgaria and region of the Danube Delta are expected to face severe droughts and water shortages. This will in turn affect water quality. In periods of drought and high temperatures less flow will enhance eutrophication and can trigger toxic algal bloom. Pollutants that originate from point and diffuse sources are less diluted, so concentrations of dangerous and emerging substances will increase. Drought will increase the demand of water (agriculture, human consumption, cooling), which in turn can enhance the lowering of flow and water tables and impaired water quality.

The CarpathCC project assessed the potential impacts of climate change on river runoff. The discharge of rivers in the Northern Carpathians is expected to increase in the winter and early spring months and substantially reduce for the summer months. Autumn months show no characteristic trends. The rivers of the Eastern Carpathians have a more homogeneous trend in water discharge, with annual discharge 3 to 11% below the current. This general decrease is caused by the decrease of the precipitation for spring, summer and mainly autumn. The autumn decrease can be 11 to 20% of the current precipitation. Only winter precipitation is projected to increase substantially, typically by 10-20%, but values as high as 45% occur.

The rivers of the Southern Carpathians show increasing winter discharge and decreasing discharge in the rest of the seasons. However - unlike the Eastern Carpathian rivers - spring, summer and autumn experience very similar drops in the discharge values. The annual decrease of discharge is projected to be around 10% relative to current values. The increasing winter and partly spring (for the NW Carpathians) discharge and the decreasing summer and autumn discharge can results in a more even discharge distribution throughout the year. The winter minimum will increase, while the late spring, early summer maximum will decrease. This can have a positive effect on any water management related, channel maintenance engineering task, while it can have negative effect in summer time when water is needed for several agricultural and ecosystem related functions and for direct urban uses as well. These negative and positive effects of floods and droughts are spatially separated, and low flow events in the foothill and plain areas can occur when there is no apparent scarcity of water in the mountainous areas (Albert *et al.*, 2013).

In a more detailed study the CarpathCC project assessed the potential impacts of climate change on river runoff in five selected river basins in Slovakia. The assessment was undertaken using the conceptual spatially lumped rainfall-runoff model Hron, and the spatially distributed model WetSpa/FRIER. These hydrological models were calibrated and validated with measured and the REMO 5.7 climate model was applied to test the sensitivity of the modelled basins to climate change. The selected five rivers are distributed almost evenly within Slovakia covering the westernmost and easternmost areas as well. The western part – where increasing precipitation is projected – is expected to show no change or even slight increase in the water discharge values. Rivers of the middle part of the NW Carpathians, like Vah, Hron and the Poprad will have an increasing water discharge for the winter and early spring months and substantially less water discharge for the summer months. Autumn months show no characteristic trends. There is a difference among these three rivers, because the Vah and the Poprad and their tributaries drain the Western Beskides and the Tatra area, where precipitation is higher and expected to stagnate or even increase a little bit in the near future according to the climate change models. The easternmost river, namely the Laborec, gets the least precipitation defined by the macroclimate and shows the highest annual decrease in discharge (Albert *et al.*, 2013).

4.2.3 Impacts on lakes

There is little specific information on the effects of flood and drought on lakes.

4.2.4 Impacts on groundwater and soil moisture

Groundwater is by far the main source of human water consumption in the Carpathian region. With regards to groundwater storage, most studies and projects studies point at a general decline in groundwater recharge for Central and Eastern Europe especially in summer, with greater reduction occurring in valleys and lowlands. Indirect, drought will increase the use of groundwater for irrigation and probably also the use for human consumption (especially in summer). Groundwater resources are more vulnerable to these climate change effects in groundwater bodies with a high ratio of withdrawals to availability, like for instance groundwater resources in Bulgaria.

For the upper Danube, the GLOWA-case study predicts a significant decline of the groundwater recharge (Mauser *et al.*, 2008). Especially groundwater bodies with a high ratio of abstractions to recharge are vulnerable to small changes in recharge and abstractions. This is for instance the case the Hungarian Great Plain Area, where a pronounced decline of the groundwater table has already started. At present, over abstraction in two of the 11 transboundary groundwater bodies of basin-wide importance (7-RO-RS-HU and 11-SK-HU) prevent the achievement of good quantitative status

(ICPDR, 2009). These resources are likely to be among the most vulnerable to small changes in recharge and abstractions.

Soil water retention plays an important role in the hydrological cycle and replenishment of groundwater. The CarpathCC project investigated the impact of soil management, changes in land use and climate change on the soil moisture regime and associated risk for landslides (Albert *et al.*, 2013). The simulations show a very complex picture. Future trends of precipitation and temperature changes will define the water regime through transpiration, evaporation and bottom water fluxes, which are highly dependent on the land use as well. Transpiration is predicted to decrease in the near and distant future under forest and arable land while grassland may show some increase for certain conditions. Evaporation is increasing for arable land and forest land uses and decreasing for the grassland uses. However, the results are very dependent on the soil types and the climate scenario. A good marker is that the number of days with optimal soil moisture content will be relatively high with relatively small differences. The study projects an increase in the number of days with optimal soil water content in dry years, although the change is not statistically significant. The change is smaller in average or wet years, and the effect of the smaller amount of rainfall can be detected in the number of days with optimal soil moisture content in the near future, especially in years with average amounts of precipitation. This is mainly due to the relatively wet climate of the mountains, which will result in a good rainwater supply and available soil water content status and a good support for the vegetation. However, the long-term projections show an increase in the number of dry days or days when the critical water content is not met between 2021–2050 and 2070–2099. These results match well with the climate and surface water drainage results, where extremes – associated with conditions where soils too dry or too wet - are expected to be more common (Albert *et al.*, 2013).

Notably, for arable land, soil management has a profound impact on soil water retention and the quantity and quality of surface and subsurface runoff. For instance, annual row-crops like corn do not protect the soil from direct raindrop impact until the leaf canopy closes. Such periods have potential risks for water runoff, adjacent soil erosion including elevated nutrient loads to surface waters. Maintaining crop residue cover until canopy closure reduces these impacts. For such, best tillage management practises are developed. There is also growing concern about soil compaction, as farm tractors and field equipment become larger and heavier. Conversely, adequate land use / land management practices may help to balance out part of the extremes (Albert *et al.*, 2013).

4.2.5 Impacts of changes in snow cover

Due to the predicted increase in temperature, snow is expected to melt earlier, resulting in snowmelt floods. A decrease in snow precipitation and accordingly in snow cover together with an earlier snow melt will trigger a shift of snow melt peaks and floods from spring to winter. Analyses of historic data show large regional and altitudinal variations, suggesting an ongoing warming process (mostly affecting areas below 1,600-1,700 m) and a lower incidence of snow (Micu, 2009). Projections suggest that due to the temperature rise the period with snowfall will shorten and the snow melting time will start earlier. As a result the amount of the snow and the number of days with snow cover will decrease in the area. In case of mountain regions, the largest snow cover decrease will be at the beginning (September) and in the end (April) of the winter season. Higher variability in snow cover (duration) can also be expected. Yet uncertainties are large. Figure 4-3 illustrates the number of years with at least 100 days snow cover in the periods 1971–2000 and 2021–2050 (Albert *et al.*, 2013).

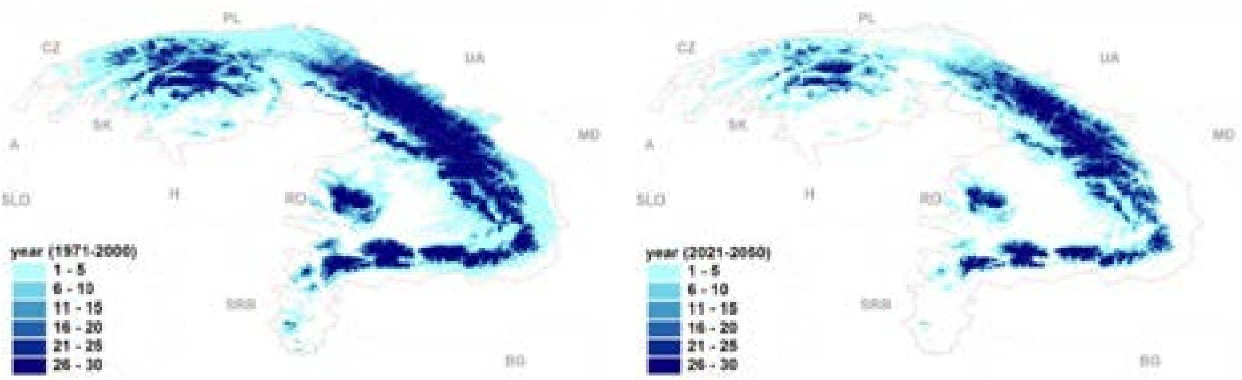


Figure 4-12 *Number of years with at least 100 days with snow cover in the period 1971-2000 (left) and 2021–2050 (right).*

The 100-day snow cover boundary is currently at the elevation of 1,250 to 1,350 m that is forecasted to rise up to 1,350 to 1,450 m by 2050. This result means that the winter precipitation will be stored in snow form for a shorter time and will be released sooner as water supply for the rivers. This is one of the reason of the forecasted increase of the winter water discharge for the rivers of the Carpathians.

4.2.6 Impacts of changes in land use and the water balance on landslides

A specific impact of climate change that is particularly relevant for the Carpathian region is the number of landslides. The Carpathians -as well as other areas in the world- have been increasingly affected by landslides and flash floods in the last few decades. Climate change is thought to be one of the main reasons for increased risk of landslides. Severe rainstorms and extreme wet periods will contribute to the development of flash floods and landslides, thus the number of these events, and their severity, is likely to increase in the future. Any kind of prevention activity requires an understanding of the development processes and of the main environmental factors that affect their spatial distribution and occurrence.

The most common approach to analyse risks for landslides is the landslide susceptibility map, which shows the probability of landslide events in a certain area based on the existence of the most important contributing factors. In the CarpathCC project, a Landslide Susceptibility Index was applied to characterise future trends in landslide events in the Carpathian region. The results are summarized in Figure 4-4.

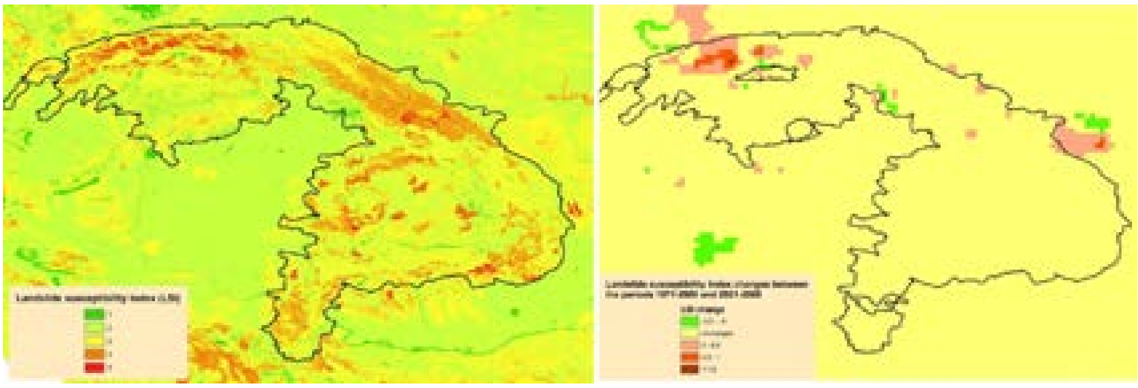


Figure 4-13 *Changes in Landslide Susceptibility Index between 1971–2000 and 2021–2050.*

The results show that the Carpathian region in general is severely affected by landslides, since environmental conditions in the area favour landslide development. More than 65% of the area belongs to the medium, high and very high susceptibility classes. Areas with high and very high susceptibility are located mainly in the outer bend of the Northwestern Carpathians — the flysch zone of the Northeastern and Eastern Carpathians, the Carpathian Bend, the Banat Mountains and the Apuseni Mountains. In these areas, slopes exceed 12 to 15% and the lithology comprises sedimentary rock formations — mainly Carpathian flysch and sandstone with clay bands — and clayey Pannonian sediments in lower-lying areas such as the Transylvanian Depression.

Slope and lithology have been identified as the most significant factors in the indication of landslide probability. Susceptibility due to the occurrence of these two factors may be exacerbated by inappropriate land use. Forest cover holds the surface and significantly decreases susceptibility to landslides. Forests have strong and deep root systems that physically bind the layers and block landslides. Forest cover also decreases landslide susceptibility by removing large amounts of water from the soil. Removing vegetation for farming, or overgrazing an area (commonly by sheep), speeds up surface runoff and causes severe erosion, often forming deep gullies and removing huge amounts of soil material. These gullies destabilise the slopes and may later cause local landslides. Pastures on sloping land used for intensive grazing are also in danger. The surface of soils stabilised by the shallow root systems of grass cover may experience a process known as ‘soil creeping’, when the soil surface starts moving downwards, slowly creating a wavy surface. This surface sheet may also be subject to surface pressures, such as frequent animal traffic, which makes it more vulnerable to erosion.

Two periods 1971–2000 and 2021–2050 are compared in Figure 4-4. In the latter period, a significant increase in LSI was detected for certain areas. Although the spatial distribution does not greatly change, hotspots will probably receive more precipitation, while the maximum daily precipitation remains unchanged for the majority of the Carpathians. This simulation result corresponds with the common scientific understanding that the intensity of rain may increase while its distribution in time becomes more uneven. A significant increase is seen only in the outer bend of the Northwestern Carpathians — that is, the area northwest of the High Tatras (the Zapadne Tatry area). As a consequence, there may be an increase of one unit in the LSI in this area, thus susceptibility may increase by 10 to 15%.

4.3 Key factors co-determining impact and vulnerability of water resources

Vulnerability of water resources to climate change largely depends on altitude, land use and topography. For instance, areas in the vicinity of rivers and flood plains are more likely to be affected by floods. Flooding events are often influenced by a combination of natural and anthropogenic factors. Extreme events in precipitation will greatly enhance the chance of the occurrence of floods. Improper land use adds to this equation. For instance, deforestation will decrease the extent to which water can infiltrate and soil can provide water retention, therefore increasing the risk of runoff and eventually flooding. Also, settlements are often placed near rivers and lakes, making them vulnerable for flood-related damage. By altering the river profile and cutting of floodplains the space for the rivers is reduced, making them more prone to higher water levels and eventually flooding.

4.4 Policy (objectives) that can be affected by climate change impacts

CarpathCC SR1 (Ignjatovic *et al.*, 2013) has assessed potential impacts of climate change on the implementation of the EU Water Framework Directive (WFD, 2000/60/EC) and the European Flood Directive. It includes an evaluation of the possibility to achieve good ecological status in river systems under climate changes. A first step is made in assessing the most affected river basins in the

Carpathian region, in terms of water parameters that are indicative for ecological status (Water Framework Directive). These are:

- Flow conditions (projected change ratio between 1971–2000 and 2021–2050):
  - Increase in average winter precipitation
  - Decrease in precipitation in already dry months
- Thermal conditions (projected change ratio between 1971–2000 and 2021–2050):
  - Change in average annual temperature
  - Number of days with water temperature < 4°C

Figure 4-5 shows the aggregated results for the analysis. The impact score is calculated as the sum of the four mentioned variables (ΔQ, mQ, T, N), multiplied to appropriate normalisation coefficients. In the basins with highest impact score the success of the Water Framework Directive is most likely to suffer from climate change. Ignjatovic *et al.* (2013) notes that this spatial analysis of most affected river basins must be considered as a first simplified identification. More advanced spatial analysis and modelling of the expected impacts would have to be developed using combinations of spatial data on temperature and precipitation changes that has been collected in the CarpathCC project, along with additional data about elevation (DEM), human pressure (monitoring data from WISE/member states) and reference sites (WISE/member states).

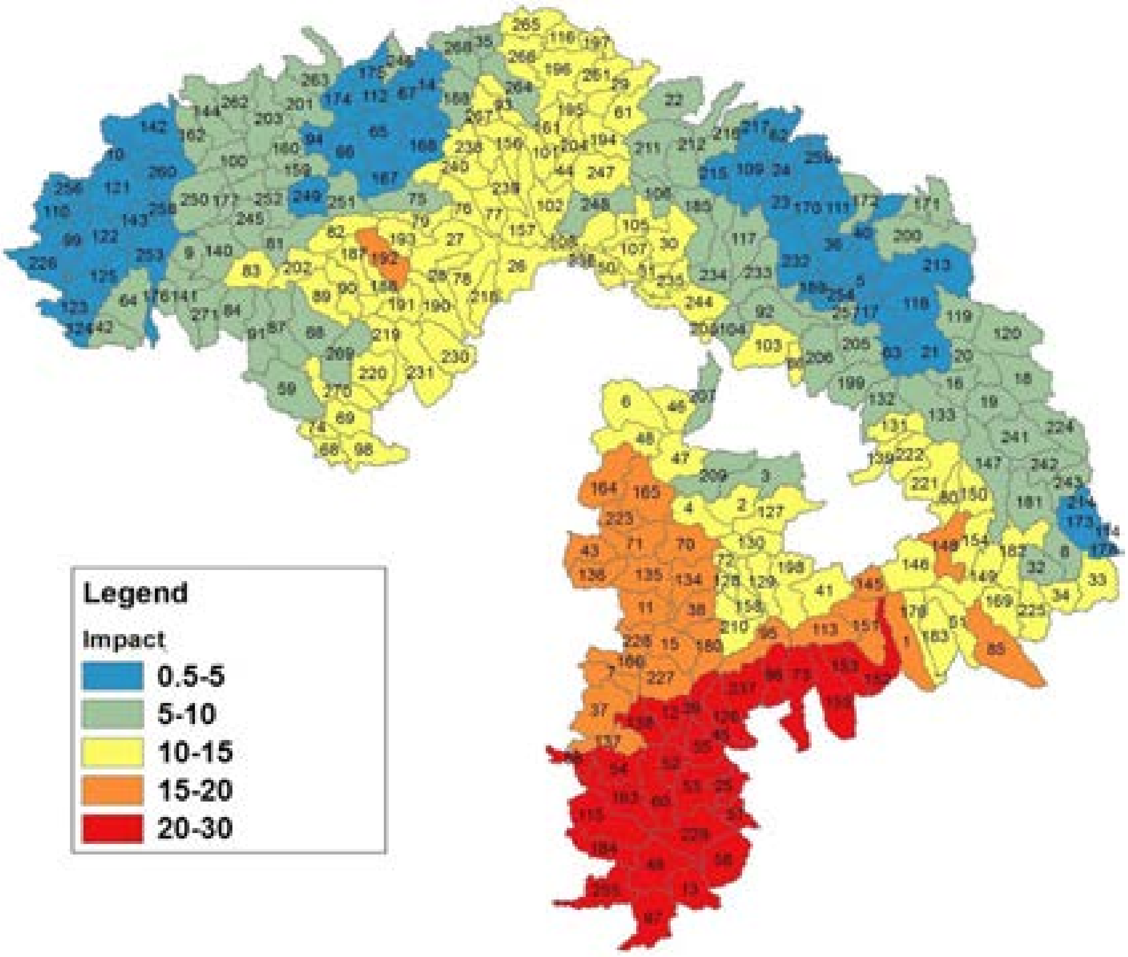


Figure 4-14 *Preliminary identification of most impacted river basins in the Carpathian region.*

From this work the following conclusions are derived (Ignjatovic *et al.*, 2013):

- Projections for average water temperature in summer reaches an increase of 4° C or above, which is expected to have definite impacts on aquatic ecosystems in the form of a decline in temperature-intolerant and oxygen-intolerant species, algae blooms, etc. The more frequent expected extreme high values for water temperature affect aquatic abiota directly by exceeding species thermal tolerance, as well as indirectly through the deterioration in oxygen conditions;

- Reference sites are of key importance for providing the monitoring data necessary for the justification of the climate trends, their environmental impacts and progress towards the goals of the WFD. The number of reference sites currently reported to the EC and officially published is insufficient. The network of monitoring sites should be improved, with a special focus on reference sites, including the identification of new ones, particularly in EU candidate and neighbourhood countries. In particular, monitoring information from Ukraine is not currently available or is not compliant with WFD requirements. The number of sampling parameters and the metrics of the monitoring programmes should include markers most sensitive to climate change impacts;
- Open access to EU-level spatial and monitoring data has substantially improved over the last years, but further improvement is still needed;
- There is not sufficient justification for the climate adjustment of criteria for defining the reference conditions and border values of the classification systems for ecological status *for the water management cycle 2016–2021*. Classification systems for ecological status for this water management cycle should be based on experience gained during the present period and the results of the intercalibration exercise. Yet, climate projections *for the period 2021–2050* do suggest a need for adjusting the reference conditions and border values of the classification systems, particularly in South Eastern Europe. Such adjustment should be based on climate projections, related hydrology data, and monitoring data from the first and second water management cycles;
- Further studies on the response of ecosystems to climate-induced stressors are necessary in order to develop more precise and reliable projections of impacts and WFD-compliance;
- New reference sites should be established in locations with high ecological status/ reference conditions in the southern part of the Carpathian region, where greater changes in thermal and flow conditions are expected. The establishment of such sites in the water management period 2016–2021 will allow the fine-tuning of the reference conditions based on real data. In particular, the establishment of additional monitoring sites is recommended for river basins that are not currently covered by the monitoring network;
- The most affected river basins should be the focus for the development and application of adaptation measures in the framework of river basin management plans in order to achieve and sustain good ecological status. Such adaptation measures could include the adjustment of permits for water abstraction/water use/pollution discharge; the introduction of smart irrigation systems; the afforestation of catchment areas; the management of catchment land use to reduce diffuse nutrient loading and soil erosion; and the restoration of riparian floodplains to buffer extreme runoff and reduce nutrient flow.

4.5 Potential adaptation measures

Measures to prevent flood damages include non-technical measures, such as river restoration, changing land use, afforestation, warning systems, preparation programmes and technical constructions like dams, dikes or retention reservoirs. To prevent or reduce water scarcity, typical adaptation measures that are actively implemented in mountainous areas are aimed at increased efficiency of water use, water storage and introducing water saving measures. Examples include improved irrigation techniques, new reservoirs, rainwater harvesting, wastewater and grey water re-use.

For advancing water storage, firstly adaptation of the management of existing water infrastructure has to be taken into consideration. Model-based investigation showed that low-flow provision from a reservoir on the Mures River Basin can be improved by 20%, merely by modifying the management. If adjusting management is not sufficient, then storage capacities can be improved. Structural measures include building traditional reservoirs, water tanks and subsurface reservoirs. Another promising structural measure is the installation of *rainwater harvesting systems* on slopes. Besides flood and low-flow control, these microstructures (terraces, bunds, micro-levees) have additional, local-scale advantages: mitigation of surface erosion, counteracting the desiccation of forests and the cooling effect of increased evapotranspiration. Subsurface water storage can be enhanced by improving infiltration. This can be achieved by *protecting and restoring open grasslands*, where losses due to interception and evapotranspiration are much less than in forested areas. This land use measure is especially recommended for the karstic systems in the Carpathians, where grasslands mean the primary sources of water supply for the sub-surface water resources. Finally, storage capacities of lands can be increased by *altering the road network*, which is quite extensive and dense, especially in the Eastern Carpathians. Intensively used dirt roads act as drains accelerating the runoff process, in addition they cause local erosion problems. Eliminating roads necessitates the adjustment of land use. For this purpose activities requiring frequent transportations (e.g. hay production) have to be replaced by transportation-free land uses, such as grazing or nature conservation.

Integrated Water Resources Management (IWRM), a participatory and implementation process, is generally recommended against flooding events, droughts and water scarcity. IWRM elaborates on managing water resources at basin scale, optimizing supply and demand, establishing policies and utilizing an intersectoral approach to decision-making. To ensure the viability and long-term application of measures, a number of precautionary actions is considered essential in order to gain full political and stakeholder support. For instance, the legal framework is crucial to support pro-active planning and the implementation of adaptation measures. Furthermore, raising stakeholder awareness about the need to implement certain adaptation actions can prevent future conflicts. Market-based economic incentives may be considered to encourage the private sector engage in adaptation measures.

Below, the adaptation measures are listed for coping with impacts on water resources (floods, deterioration of water quality and droughts). Adaptation measures include non-technical measures and technical measures.

Table 4-3
Adaptation measures against flood threats.

Non-technical measures	Technical measures
Afforestation	Reallocation of houses to less vulnerable areas
Warning systems and preparation programmes	Ground floor space
Acquisition of operational flood prevention and cooperation between authorities	Retention reservoirs for floods
Incentives to provide flood storage	Increasing storage capacity of reservoirs in rural and urban areas
Rainwater and storm water management in urban areas	Increasing water discharge capacity of rivers and floodplains (deepening of river meadow, obstacle removal)
Changing land use and strategic zoning	Acquisition of temporary flood control structures
Strengthening societal resilience	Dike and dam construction and improvement
Increase natural retention and floodplain restoration (room for the river)	

Table 4-4
Adaptation measures for water quality.

Non-technical measures	Technical measures
Develop monitoring programmes for surface water quality	Install purification facility
Develop management strategies for fertilizer and waste	Create areas for lagooning, surface impoundment
Adopt quality goals and develop management plans	Different fertilizer (slow release of nutrients, prevent leaching of excess fertilizer)

Table 4-5

Adaptation measures against water scarcity and droughts.

Non-technical measures	Technical measures
Adopt long-term perspective in planning, modelling and management	Irrigation strategy
Weather derivatives	Move power plants to coastal area
Restrictions and consumption cuts	New water supply options
Drought management plans	Sustainable drainage systems
Droughts communication system	Water sensitive urban design
Monitoring to provide information that may indicate inception of drought	
Raise awareness for efficient water use	
Introduce drought resilient crops	
Silvicultural management – improve tree water balance	

Uncertainties form a barrier for the implementation of adaptation measures. These include the limited information on local impacts on water availability, quality and demand due to uncertainty in downscaling climate models, lack of long-term planning strategies, coordination and management tools, and the lack of region specific water-related adaptation measures for climate change impacts. E.g. above-mentioned adaptation measures for water scarcity are tailored for the European Alps, and may not be directly applicable to the Carpathian region. Differences in demography, environment and land use demand a case-specific approach. Still, the experience from outside the region may be used as a basis, to be tailored into location specific viable adaptation measures.

4.6 Integrated assessment of water resources vulnerability

There is clear spatial variation in the identified climate-induced trends in thermal and runoff conditions. While the northern part of the Carpathian region is insignificantly or moderately affected, the southern part is expected to be highly affected. The most affected river (sub-)basins are expected to be the southern ones (located in RO, SRB, BG), including the Danube, Cosustea, Mlava, Timok, Motru, Blahnita, Morava, Gilort and Olt. As opportunities for adaptation are considered less spatially varied and will depend on financial resources, these (sub-)basins are expected to be the most vulnerable as well. Cooperation in the implementation of the Water Framework Directive offers opportunities for the development and application of adaptation measures in the framework of river basin management plans in order to achieve and sustain good ecological status.

5 Ecosystems: impacts of climate change threats, adaptation & vulnerabilty

This chapter describes for the main ecosystems in the Carpathian region their current status, main impacts, adaptation options and vulnerability.

5.1 Forest Ecosystems

5.1.1 Current status

The Carpathian region is home to the largest European continuous forest ecosystem, which provides an important refugee and corridor for the migration of diverse organism and harbours exceptional biodiversity. Recently, forest damage in the Carpathians is found to increase (Kuemmerle *et al.*, 2009; Hlásny and Sitková, 2010). Wind damages followed by insect pest outbreaks, outbreaks of defoliating insects as well as increasingly recognised effects of drought have been observed to compromise the stability of Carpathian forests and sustainability of the provision of forest ecosystem services. An effect of most of injurious agents is expected to be amplified by climate change, though interactions between climate, forest disturbance regimes and forest management have not been thoroughly understood yet.

This chapter gives an overview of the main forest types in the Carpathian region and their vulnerability to climate change. Information on forest types and distribution was mainly derived from 'Current State of Forest Resources in the Carpathians' (Anfodillo *et al.*, 2008), EEA Technical report 'European forest types Categories and types for sustainable forest management reporting and policy' (EEA, 2006), and 'Map of the Natural Vegetation of Europe' (Bohn *et al.*, 2000), with additions from research articles and the CarpathCC project SR2 (Barcza *et al.*, 2013).

In the following, the main forest types in the Carpathian region are presented based on the main altitudinal belts. For each altitudinal belt, the main forest types were identified based on available literature. For each forest type, the geographic distribution, the main threats arising from climate change, the response of the ecosystem to these threats and possible adaptive measures are described and sources of relevant literature are presented. Remnants of natural forest types that have been reduced in their extent are listed separately.

5.1.2 Main impacts of climate change

Climate projections imply that some climatic variables, mainly those related to drought, may exceed the threshold of the persistence 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 diseases distribution as well as potential influx of new pests can critically affect some of the Carpathian forests.

Below, possible climate change impacts are reported per altitude ranges and key species. These impacts were compiled in particular from 'Impacts of Climate Change on European Forests and Options for Adaptation' (Lindner *et al.*, 2008) with supporting material from research papers and supplementary data from the European Environment Agency's European Nature Information System. In addition, we report on climate change induced forest tree species shift in the Carpathians.

5.1.2.1 Impacts on altitude ranges and key forest tree species

Colline belt (<600 – 650 m a.s.l.)

The colline vegetation zone occurs in particular in the Carpathian basin. With mild and warm temperature, water is the limiting factor for vegetation. The typically deciduous forest types are part of a predominantly agricultural matrix that also includes habitats like floodplain forests. The altitudinal limit of the colline belt differs slightly between the different sub-ranges. Forest types that are most common, either due to as a result of human intervention including conversion of natural forest types to commercially or otherwise more interesting types, conversion to agriculture, particularly on richer soils. The major threat from climate change is drought conditions that may be exacerbated by the use of water for agriculture and settlements. Increasing damage from pathogens and insects are secondary threats. The main functions of these forest are recreational opportunities, carbon sequestration, and moderation of local climate. Due to the generally high degree of human modification biodiversity is often only of secondary importance.

1) ***Pedunculate oak (Quercus robur) - hornbeam forest (Carpinus betulus) (Sabor, 1993; Bohn et al., 2000; Grodzińska et al., 2004; EEA, 2006; Anfodillo et al., 2008; Lindner et al., 2008; Planinšek et al., 2011).***

Naturally occurring in entire region; on wetter soils; not very common anymore; often replaced by agriculture but also by forest plantations (*Picea abies*); main secondary species of current forests include *Acer* spp. and *Fraxinus* spp. **Ecosystem function:** recreational opportunities; carbon sequestration; moderation of local climate; natural stands: biodiversity.

Increase in drought conditions may lead to a shift in species composition and dominance away from Q. robur to more drought-tolerant Quercus species (eg. Q. petraea, Q. cerris; Q. pubescens) and or Tilia; decline of secondary species that are sensitive to drought. Vulnerability to climate change is moderate to high; Species are generally adapted to drier conditions; increased drought stress increases vulnerability to insect (eg. oak processionary moth) and pathogen (eg. root decline) damage; extended droughts may be problematic for some species.

2) ***Sessile oak (Quercus petraea)-hornbeam (Carpinus betulus) forest (Sabor, 1993; Bohn et al., 2000; Grodzińska et al., 2004; EEA, 2006; Anfodillo et al., 2008; Lindner et al., 2008; Planinšek et al., 2011).***

Naturally occurring in entire region; on drier soils; not very common anymore; often replaced by agriculture but also by forest plantations (*Pinus* spp.); main secondary species of current forests include *Acer* spp. and *Tilia* spp. and also *Pinus* spp. in human modified stands which are generally species poor. **Ecosystem function:** recreational opportunities; carbon sequestration; moderation of local climate; natural stands: biodiversity.

Decline in growth and regeneration; changes in species composition; extended drought conditions may lead to forest collapse and steppe formation. Drought-tolerant sessile oak forests will likely increase in their extent in areas of land abandonment. Vulnerability to climate change is moderate; Species are generally adapted to drier conditions; increased drought stress increases vulnerability to insect (eg. oak processionary moth) and pathogen (eg. root decline) damage; extended droughts may be problematic for some species.

3) ***Pinus plantations (Yatsyk, 1996; Kuemmerle et al., 2007; Anfodillo et al., 2008; Lindner et al., 2008).***

Plantations of *Pinus* spp., part. *P. sylvestris* and *P. nigra* established across the entire region replacing natural forests, part. natural beech and oak forests. **Ecosystem function:** Wood production.

Under limiting conditions (poor soils and low moisture) stress-related mortality may lead to collapse of forest to steppe-like vegetation or conversion to oak or non-native invasive species. The vulnerability to climate change is moderate to high; The main threat are storms. Increased drought conditions increase stress-related mortality. The risk of fire increases. The risk of regeneration failures of pine whether natural or artificial will increase; Susceptible to erosion and mudslides.
Relict forest

Remains of naturally occurring forest types that have declined in their extent due to human modification and also due to environmental pollution (Anfodillo *et al.*, 2008). These forests typically occur only locally and are fragmented, which increases their vulnerability to climate change impacts. Generally they are of high conservation value due to their threatened status. As their natural occurrence is on richer soils, they often are species rich with a high value for biodiversity. **Ecosystem function:** Biodiversity

Ash (*Fraxinus* spp.) and oak (*Quercus* spp.) - **ash forests** occur mainly in the North in cooler climate; restricted to rich fertile soils; stands have mainly been converted to agriculture; main secondary species include *Ulmus* spp.; *Acer* spp. *Quercus* spp.; remaining stands are used for wood production and water protection. Ash forests respond to climate change by a shift in species composition. Vulnerability to climate change is high due to sensitivity to drought (EEA, 2006; Anfodillo *et al.*, 2008; Lindner *et al.*, 2008).

Maple (*Acer campestre* and *A. tartaricum*)-oak (*Quercus* spp.) **forest** are (very) rare; restricted to moist conditions and rich soils; main secondary species include *Q. robur*, *Fraxinus excelsior*, *Tilia cordata*, *Acer* spp., *Ulmus* spp. These forests respond to climate change by a shift in species composition; loss of this forest type. Vulnerability to climate change is very high as this forest types is already rare and water limitations will increase the stress on these forests; particularly *Quercus* spp. are susceptible to insect and pathogen damage (Bohn *et al.*, 2000; EEA, 2006).

Lime (Tilia cordata) – **Oak** (Quercus spp.) **forests** are rare, found predominantly in the polish part of the Carpathian region; restricted to moist conditions and rich soils; main secondary species *Ulmus glabra* and *Quercus* spp. (in the north predominately *Q. robur*; in the south predominately *Quercus sessilis*, *Q. cerris*, *Q. pubescens*, *Q. frainetto*). These forests are listed in EU Habitats Directive Annex I. They respond to climate change by a shift in species composition to more dominance of *Tilia*; however *Tilia* is highly sensitive to browsing by deer and other ungulates; forest type may be replaced by more competitive beech forests; risk of decline or loss of this forest type. Vulnerability to climate change is high as drought-stress increases; particularly *Quercus* spp. are susceptible to insect and pathogen damage (Bohn *et al.*, 2000; EEA, 2006).

Lime (*Tilia* spp.) **forests** are rare; typically with mixed canopy composition, including *Acer* spp., *Fraxinus* spp., *Quercus* spp., *Ulmus* spp.; on rich and moderately rich soils; listed in EU Habitats Directive Annex I. These forests are listed in EU Habitats Directive Annex I. They respond to climate change by a shift in species composition to more competitive species ; such as beech; risk of decline or loss of this forest type. Vulnerability to climate change is high due to increased drought stress which favours other species such as beech (Bohn *et al.*, 2000; EEA, 2006).

Montane (600 – 1500 m a.s.l.)

The montane belt follows the colline belt The climate becomes harsher with lower temperatures. Agriculture is still a dominant land use, especially in the sub-montane part up to ca. 1250 m. the montane belt reaches up to ca. 1500 m with slight regional differences in the altitudinal limits.

Beech is the dominant species in the sub-montane part whereas conifers start to dominate in the mid and high montane part. The region harbours the last remaining natural beech forests. Norway spruce has been planted extensively for production and often forms homogenous even-aged stands. Increasing drought conditions and more severe storms are the major threat from climate change. There is also an increased risk of forest fires and, especially in the spruce plantations, increasing damage from pathogens and insects can be expected. The main functions of the beech forests are biodiversity, climate regulation, erosion control and water retention. The pressure from tourism and recreation is expected to increase in the beech forests and may pose a threat to biodiversity (Webster *et al.*, 2001).

1) Carpathian sub-montane and montane beech (Fagus sylvaica) forests.

Occur naturally in entire region; potential altitudinal range 600 – 1200 m; at lower elevation starting also from ca. 400 m a.s.l. typically as a result of human intervention; at higher elevations ca. 1100 – 1200 m often replaced by fir and spruce; the main secondary species are hornbeam and oak at lower elvations, sycamore maple (*Acer pseudoplatanus*), mountain ash (*Fraxinus excelsior*) and elm (*Ulmus glabra*) within the main beech zone, silver fir (*Abies alba*) and Norway spruce (*Picea abies*) at higher elevations; the only 'natural'montane beech forests that rmain in Europe. **Ecosystem function:** Biodiversity; recreational opportunities; carbon sequestration; moderation of local climate; water retention; fuel wood.

Generally an increase in drought conditions will result in a decline in beech forests; At lower altitudes when drought becomes the limiting factor oak is more competitive than beech and will gradually replace beech. The vulnerability to climate change is moderate to high; summer drought and winter temperature are the most limiting factors for beech; increasing drought conditions may limit beech growth and regeneration especially in the southern Carpathians but also in other regions with shallow soils; an increase in temperature may be beneficial for beech growth where precipitation is sufficient and at the upper altitudinal limit of beech; at the upper altitudinal limit however an increase in storm events may cause increasing damage (Korpeĺ, 1995; Standovár and Kenderes, 2003; Neuhäuslová-Novotná, 2009).

2) Beech – Silver fir (Abies alba) – Norway spruce (Picea abies) forests.

On south-facing slopes in the south, conifers are often replaced by deciduous species such as acer, alder, ash; the limit of beech is at ca. 1200 m a.s.l., and of fir at ca. 1400 m; where not converted to planation forests these forests are the last remaining natural stands of this forest type. The natural forests are important as protective structures against avalanches, rock falls and landslides; they provide important services including water retention, climate modification and biodiversity. Important secondary species include mountain ash, sycamore maple and rowan. Douglas fir may occur as additional species in plantation forests. **Ecosystem function:** Biodiversity; recreational opportunities; carbon sequestration; moderation of local climate; water retention; fuel wood; protection

Climate change will result in a shift in species composition. Especially spruce but also beech is susceptible to drought. There is a risk of encroachment of non-native species such as Douglas fir (*Pseutotsuga menziesii*) from planted production forests; natural regeneration after storm events may be limited due to water limitations and herbivory. The vulnerability to climate change is high; due to temperature increase the dominance of beech is likely to increase; spruce is very susceptible to drought; the damage caused by storms is likely to increase especially in areas with higher spruce and beech dominance; natural regeneration of especially fir is threatened by an increasing density of herbivores (Korpeĺ, 1995; Standovár and Kenderes, 2003; Grodzińska *et al.*, 2004; Kricsfalusy *et al.*, 2004; Lindner *et al.*, 2008).

3) Montane Norway spruce.

This forest type occurs from ca. 1100 to 1500 moften over-mature and in decline (Moravčík, 2007); on south-facing slopes in the south, conifers are often replaced by deciduous species such as acer, alder, ash (Grodzińska *et al.*, 2004); planted stands typically have a homogenous age structure and are species poor. **Ecosystem function**: Water retention; carbon sequestration; protection; wood production (part. plantations).

This forest type will decline in extent due to climate change; species shifts with more deciduous tree species. The vulnerability to climate change is (very) high; Spruce is particularly vulnerable to the effect of droughts and storm; increased drought stress increases the vulnerability to insects such as the spruce bark beetle (*Ips typographus*) and pathogens (Korpeĺ, 1995; Standovár and Kenderes, 2003; Grodzińska *et al.*, 2004; Moravčík, 2007; Lindner *et al.*, 2008).

(Sub)alpine (>1500 m a.s.l.)

In most parts of the Carpathian mountains closed-canopy montane spruce forests form the uppermost forest type with an average timberline that corresponds here with the tree line of ca. 1500 m (Kricsfalusy *et al.*, 2004). Sub-alpine conditions are reached only in some parts of the Carpathian and prevail up to the timberline at ca. 1800 m with regional differences (Plesnik, 1978). Sub-alpine forests are often modified by human activity including the use as mountain pastures. The natural treeline is often suppressed and forest extent is reduced. Alpine conditions are reached in very few areas only such as the Tatras mountains in the north and several ranges in the south. An increase in temperature will be beneficial for tree growth in these areas. The slow process of soil formation and grazing will however limit the upslope expansion of forests. Harsh environmental conditions (low temperatures, short growing season, high radiation) limit forest development; closed forests may be found up to the timberline at ca. 1800 m depending on the region. Above the timber line to the tree line at ca. 1900 m (Kern and Popa, 2008) trees occur only in small groups and show stunted growth. Tree species in this zone may not be able to climb with increase in temperature and may be replaced.

1) ***Subalpine Norway spruce forests.***

Subalpine Norway spruce forests form the main forest type in the sub-alpine zone in the Carpathian mountains. Unlike many Norway spruce forests at lower elevation, sub-alpine spruce forests are of natural origin and occur up to ca. 1750 to 1800 m as closed forests. Secondary species are *Larix* spp. and *Pinus* spp. **Ecosystem function:** Biodiversity (subalpine Norway spruce forests are recognised to harbor unique species assemblage in the herb and shrub layer in the forest class “Vaccinio Piceeta”); they are important as protection forests and for erosion control and water retention.

Climate change is expected to result in a shift to Larix spp.; declining extent; if water and nutrients (part. nitrogen) are not limiting increased growth rates can be expected as a function of increasing temperature and increasing CO_2. The vulnerability to climate change is generally high; the main threats are storms and pests (spruce bark beetle [*Ips typographus*]) but also extreme precipitation events; due to the increase in temperature, the extent of sub-alpine spruce forests will decrease (Korpeĺ, 1995; Szewczyk *et al.*, 2011).

2) ***Subalpine larch (Larix spp.) - Swiss stone pine (Pinus cembra) and subalpine Swiss stone pine forests.***

Tatra mountains, southern Carpathians (Butschetsch, Fogarasch, Regezat Montains; 1550 m to timberline as closed forest). Particularly Swiss stone pine is also found above the timberline in small groups of tress and often with stunted growth; two Larix species occur: European larch (*Larix decidua*) and *Larix polonica*, the latter listed as an endangered habitat in the Bern Convention. **Ecosystem function:** Protection; Biodiversity; Habitat for European Nutcracker (*Nucifraga caryocatactes* L.), listed in EC Habitat directive Annex I, habitat 9420.

Climate change is expected to result in upslope shift; reduced regeneration success; declining extent; increasing dominance of *Larix* spp. Vulnerability to climate change is very High; limiting factors are drought, depth and duration of snow cover, pathogens; response of the European nutcracker to climate change as this bird is important for the dispersal of *P. cembra* seeds (Starmühler and Starmühler, 1995; Boden *et al.*, 2010; Casalegno *et al.*, 2010).

3) ***Relict forest - Alpine Scots Pine and Black Pine forests.***

Occurs as individual trees with stunted growth up to ca. 2 m high; Found in Tatra, Bihor, Calamani, Bucegi, Retezat mountain ranges; typically on very steep and southern exposed limestone sites; up to > 2000 m in the south; main associated species Juniper communis. **Ecosystem function:** Biodiversity; habitat type associated with endangered shrub and herb species; listed in EC Habitat directive Annex I. Most likely effect of climate change is local extinction. Vulnerability to climate change is very high (Bohn *et al.*, 2000; EEA, 2006).

5.1.2.2 Climate change induced forest tree species shift in the Carpathians

In the previous section we discussed impacts on individual forest tree species and altitude zones. Here we report on the climate change induced species shifts. Species shift is an inherent adaptation mechanism of species to cope with changing environment, which allows species to follow the shifting climatically optimal sites. Inability of species to follow the shifting climate may cause population decline and, in some cases, extinction. Species shift may represent a threat to biodiversity, which is especially pronounced in mountain areas, where species have limited options to migrate or adapt.

The 'SR2 study' of the CarpathCC project focused on the two most distinct features of species shift, i.e. species expansion upward in elevation and northward in latitude, including tree line shift, and on the retraction of lower range limit, which may be induced by water scarcity (Barcza *et al.*, 2013). The study showed that there is limited information on observed species shift; evidence is scarce and unpersuasive in some cases. Species shift has generally not been addressed as topic of higher importance attracting attention of decision makers and scientists.

In the view of collected and evaluated observational evidence and projections, the changes in species composition, which are likely to occur in the Carpathians, can be summarised as follows:

- In the planar to colline zone, continuous change of present oak forests towards oak forests with a higher share of drought tolerant species, such as *Quercus cerris*, may occur. Even the occurrence of species such as *Q. frainetto* or *Q. illex* can increase mainly on southern regions, or such species can be artificially introduced within the frame of forest adaptation. The proportion of other drought-tolerant species of lesser importance may increase as well;
- Although European beech has been frequently considered as important component of temperate forests adaptation to climate change, its climatic sensitivity implies presence of beech mainly in higher elevation, and it should be treated very carefully in drought exposed sites also considering the threat of newly emerging insect pests;
- Expansion of suitable conditions for oak species suggests an increase of their share across almost the entire Carpathians, except for the highest elevations. Increased forest dynamics in the present contact zone of oaks and beech can be expected;
- Expansion of conditions suitable for oaks and decrease in conditions suitable for beech implies appearance of communities composed of oaks and conifers in higher elevations. Such communities rarely occur in some valleys of the inner Carpathians but their sensitivity to climate change and future prospects have not yet been investigated;
- Spruce needs to be thought of as highly vulnerable species. Climate change is likely to create an additional pressure on decrease of spruce population, except in the highest elevations where spruce occurs naturally.

The above described developments need to be viewed in the context of the following factors:

- As most of the Carpathian forests are managed, the rate of projected changes will depend to a large extent on forest management, and human support to inherent adaptation mechanisms;
- Detrimental effects of species shift may occur in case of shifting tree line. Such shift may reduce the extent of valuable alpine habitats fostering vulnerable flora and fauna, as these communities have minimal or no opportunities to migrate or adapt. In such cases, forest management may act to preserve the vulnerable species and communities by eliminating the shifting vegetation from lower elevations. To a certain extent this might interfere with the projections of species shift;
- All the changes above are expected to be more pronounced in the Eastern, Southern and Serbian Carpathians as compared with Western Carpathians, due to an increase in climatic exposure from north-west towards south-east. This tendency has been confirmed by all climate change scenarios that were explored.

5.1.3 Factors co-determining impacts and vulnerability

As in many other regions forests in the Carpathian region are heavily modified by human activities; forests have been cleared for agriculture and natural forests have been converted to plantation forests resulting in forest fragmentation (Kozak *et al.*, 2007). In the communist era, forest were overexploited (Anfodillo *et al.*, 2008) and recently illegal harvesting has been identified as a threat (Brandlmaier and Hirschberger, 2005) although studies indicate a recent increase in forest cover in the region (Kozak *et al.*, 2007). Besides forests in use for production, the Carpathian region still contains vast tracks of near-natural forests (Anfodillo *et al.*, 2008). As a result of the heavy use especially in the communist era, forests are comparatively young (Muica and Popova-Cucu, 1993; Anfodillo *et al.*, 2008). Due to the current age structure of the forests, generally good growing conditions and the recent expansion of forest cover, the growing stock is increasing (Anfodillo *et al.*, 2008).

Climate change impact on pests and pathogens in the Carpathians and anticipated threats.

Forest pests and pathogens can be thought of as climate change driven agents, the effect of which may induce critical disruption of the provision of forest ecosystem services and functions. The main reason for this is the high sensitivity of mainly insect pests, which may respond to even minor changes in climate by substantial changes in their population dynamics and distribution.

Activity of biotic agents has, in the recent decades, been elevated in many regions of the Carpathians and there are indications of climate change effects on population growth of some species. There are indications of increasing impact of presently occurring pests on forests, as well as potential emergence of new pests. Bark beetles of the genera *Ips* can be thought of as the most important such agent. While in the higher elevations their outbreaks can be fuelled by increasing frequency of windstorms, in lower to medium elevations, where spruce has been extensively planted in many regions, unprecedented outbreaks could be triggered by drought.

Regions affected by non-climatic stressors, such as air pollution or improper management, could be especially prone to the effects of an array of pests and diseases. Such non-climatic stressors may substantially increase forest sensitivity to climate change. For example, the region of the Western Beskids (Western Carpathians, CZ-SK-PL) represents an extremely vulnerable region containing spruce forest with highly elevated activity of biotic agents, which is declining over a large area. The anticipated amplification of this decline, as response to climate change, may critically disrupt the provision of all services and functions provided by forests, including water regulation and erosion prevention.

Lower to medium elevations of the Carpathians are expected to face an increased pressure of defoliating insects, among which the Gypsy moth (*Lymantria dispar*) can be thought of as the most important. The pest is expected to benefit from climate change, and its regular outbreaks were projected to expand over larger areas. An upward shift and alternative severe defoliations of beech have been reported from several regions in the Carpathians already (Barcza *et al.*, 2013).

Effect of changes in forest cover on the protective function of montane and subalpine forest.

Montane and subalpine forests play an important multi-functional role in stabilizing landscapes, and represent a major component of landscape aesthetics that is of importance for tourism and associated human activities. Montane and subalpine forests make almost 60% of all forests in the Carpathians, and provide a complex of forest services and functions, including their protective functions. A primary function of a protective forest is the protection of people or assets against the impacts of natural hazards or adverse climate (Brang *et al.*, 2006). The main protective functions of montane and subalpine forests encompass soil protection (i.e. prevention and mitigation of erosion and loss of soil); prevention and mitigation of avalanches, landslides, and rock falls; and preservation of water resources (Moravčík *et al.*, 2005).

5.1.4 Policy (objectives) that can be affected by climate change impacts

A dominant share of Carpathian forests is managed. Forest management practices differ in various aspects among countries, as do nature conservation policies. At the European level climate change may affect the success of implementing the EC Habitat directive and Natura2000.

The main conclusions of the assessment of forest management are (Barcza *et al.*, 2013):

- None of the Carpathian countries have directly addressed climate change in forestry legislation yet. Although this issue is usually included in the national forestry strategy plans, programmes and actions as one of the objectives, these documents do not specify any adaptive forest management strategies and ways of their implementation in forest management;
- The awareness of climate change in the Carpathian forestry community is moderate, though with large regional differences. Practitioners do not usually address climate change *per se*, but mainly with reference to actual threats; such measures can however be part of adaptive forest management;
- The regional differences are high. For example in Hungary, the private forestry sector starts considering climate change impact seriously due to organised communication. In contrast, there are indications that in the Czech Republic, in spite of great problems with Norway spruce plantations, Norway spruce is still a highly promoted species in forestry practice. In addition, the “climate-scepticism” among policy makers is sound. In Poland many private forests do not have actual forest management plans, which makes the efforts on climate change adaptation unorganized and difficult to evaluate. Restitution seems to be a problem affecting forest management in Poland and Romania.

In some regions in Romania and Ukraine, illegal logging is one of the serious threats for sustainable forest management; a direct link to poverty of local communities is however not always the case. In Hungary, a large game population seriously threatens the general implementation of continuous-cover forestry.

5.1.5 Potential adaptation measures and strategies

Forest management represents a powerful tool for forest adaptation to climate change, for example through changes in species composition. However, it could also act detrimentally in terms of overharvesting or promoting interventions opening the canopy or disrupting the water regime of forest stands. Thus mainstreaming of climate change issues into all realms of forestry – from education to policy and from monitoring to management planning – is crucial. Concepts like continuous-cover-forestry and close-to-nature forestry can be promoted to increase adaptive capacity of forests. Forest monitoring systems can be consolidated and harmonised to provide information supportive to adaptive forests management. A trans-national monitoring of invasive pests and diseases would be greatly beneficial as well.

The potential for including adaptation in forest management can be summarized as follows (Barcza *et al.*, 2013):

Hungary: Assessment of Hungarian adaptive capacity indicates the above average status as compared with other Carpathian countries. Good awareness of the private sector, which seems to exceed the other Carpathian countries, implies good adaptive capacity, especially concerning beech forests which are generally recognized as vulnerable. There are also efforts to connect adaptation in forestry with measures in climate-dependent agricultural sectors. The recent decline of economy and national policy-related threats to using European funds, however, generates concerns on enforceability of adaptive measures.

Slovakia: Research of climate change is well-supported, and the level of awareness is adequate. Modern technologies are used in forest management, a knowledge base and infrastructure allowing for climate change related hazard rating is available. Lacking cross-sectoral cooperation and insufficient transfer of knowledge from research to practice substantially hampers integrated forest and landscape management, and climate change adaptation.

Poland: Research of climate change impact on forest ecosystems and adaptation is well-developed. Although forest managers do not consider climate change as an important issue, sustainable forest management is widely accepted and supported. Lacking forest management plans in most private forests make organized adaptation difficult, mainly in regions with diverse ownership.

Romania: The level of awareness of climate change is moderate, but slowly increasing. A number of other issues such as restitution and illegal logging are more important for sustainable forestry at the current stage of development of the country. Although the overall adaptive capacity of Romania is below average of the Carpathian countries, the reforestation goals and the activities to increase the awareness of the society are promising steps towards the adaptive behaviour of the forestry sector.

Ukraine: Only the academic society is adequately aware of climate change. The adaptation plans and forest management measures have not been developed. The overall adaptive capacity of Ukraine does not reach the average of the Carpathian countries. Nevertheless, due to the disturbance problems there are tendencies towards more natural species composition and close-to-nature forest management, which can be considered as steps of forestry adaptation to climate change. More political and financial support is required to promote adaptive actions. However, such resources are currently lacking, as the country faces more urgent economic issues.

Potential adaptation measures
Appropriate adaption measures to be included in forest management strategies were compiled in particular from 'Impacts of Climate Change on European Forests and Options for adaptation' (Lindner *et al.*, 2008).

Colline belt
Pedunculate oak (*Quercus robur*) - hornbeam forest (*Carpinus betulus*): As the remaining stands are fragmented increasing the genetic diversity of stands is important to improve their adaptive capacity; removal of seedlings and saplings of competing invading species may be necessary; possibly select representative for conservation; reducing rotation length in managed forests may speed up the process of natural genetic adaptation to changing environmental conditions; the traditional management of oak-coppice may not be suitable under increasing drought conditions and either coppice rotation need to be increased or oak-coppice be converted to high forest.

Sessile oak (Quercus petraea)-hornbeam (Carpinus betulus) forest: Collection of genetic material from particularly drought-resistant populations to establish plantations; reducing rotation length in managed forests may speed up the process of natural genetic adaptation to changing environmental conditions; the traditional management of oak-coppice may not be suitable under increasing drought conditions and either coppice rotation need to be increased or oak-coppice be converted to high forest.

Pinus plantations: Conversion from even-aged to uneven-aged systems by increasing thinning intensity; group-cuts with subsequent introduction of endemic species; replacement by natural forest types, i.e. oak dominated (colline) and beech (submontane).

Relict forest: Limited potential for adaptation; Conservation trough protection and increasing genetic diversity by planting collected seed material from more drought-resistant populations aiming at increasing the extent.

Montane belt
Carpathian sub-montane and montane beech forest: diversification of the age structure of the forest; Promoting natural regeneration through thinning; ensuring species diversity by maintaining or increasing the amount of other tree species such as maple, ash and hornbeam but also fir at higher elevations; this may be achieved by group cuts of variable size; increasing the protection of the natural beech forests; shortening rotation length to speed up genetic adaptation.

Beech – Silver fir – Norway spruce forests: diversification of the age structure of the forest; Enhancing the natural regeneration by group cuts of variable size; shortening rotation length to increase genetic diversity clashes with the objective to maintain the protective function of these forests that requires a mix of old and young trees. Genetic diversity may be increased artificially by planting of more drought-tolerant provenances.

Montane Norway spruce: Increasing tree species diversity by encouraging regeneration of other species, such as fir and beech but also other, particularly deciduous species such maple, ash or rowan through increased thinnings and group cuts; diversification of the age structure of the forest.

(Sub)alpine belt
Subalpine Norway spruce forests: Limited; potential measures could be to discontinue the use of sub-alpine and alpine pastures and to allow forest succession, possible supported by planting of spruce seedlings from local provenances.

Subalpine larch (Larix spp.) - Swiss stone pine (Pinus cembra) and subalpine Swiss stone pine forests: conservation of P. cembra in present habitats; increase regeneration in higher altitudes and into other areas by planting.

Relict forest: Limited (conservation for the time being).

Integrated pest management

Integrated pest management is a promising strategy to cope with impacts of climate change. The following integrated pest management principles were found to be important for forestry in the Carpathians (Barcza *et al.*, 2013):

- Prognosis of short- to medium-term changes in pests` population dynamics and distribution are important tools for hazard rating and taking effective measures. The use of hazard rating models guiding forest management is however rare in the Carpathians; the reason for this is undoubtedly lack of awareness and insufficient transfer of knowledge from research to management;
- Conversion of present vulnerable species composition to more stable forests with lesser proportion of susceptible host plants is needed in some regions (e.g. part of the Western Beskids). Such radical changes however presume intensive cross-sectoral cooperation, which is insufficient, and current legislation does not support the integrated landscape management. This issue should be flagged, especially in the vulnerable trans-boundary forested regions with elevated activity of forest pests;
- Monitoring of forest pests and changes in their distribution and population dynamics are generally not developed enough to face the anticipated changes. Therefore consolidation and trans-boundary harmonization of monitoring systems is needed;
- In view of climate change, further education of foresters concerning newly emerging pests and anticipated climate change effects on forest ecosystems is needed. Forest management under climate change calls for consolidating the forest protection units in terms of capacity in both human and technical resources. Unfortunately their capacity at this moment is in all aspects very low across the countries of the Carpathians.

5.1.6 Integrated assessment of forest vulnerability

The CarpathCC project, SR2 *In-Depth Study on the impacts of climate change threats on ecosystems* as one of the main outputs provided the integrated assessment of forest ecosystems` vulnerability (Barcza *et al.*, 2013). The methodology that was followed was the vulnerability concept proposed by Lindner *et al.* (2008; 2010) (vulnerability = exposure × sensitivity × adaptive capacity), who applied this approach in the assessment of climate change vulnerability of European forests.

Evaluation of forest sensitivity is a complex issue, as it includes sensitivity of several forest components to a range of impact factors, with consequences on forest capacity to provide goods and services. A range of indicators was considered to evaluate the forest sensitivity to climate change in the Carpathians, and results of several tasks of the SR2 study were integrated. The integral vulnerability assessment was done with the following considerations in mind:

- Both exposure and sensitivity determine forest vulnerability, their relative importance vary substantially in time and place;
- Although adaptive capacity indicators differ between countries, it is argued that none of the countries has effectively adapted or is planning adaptation that can substantially alter vulnerability. Thus, the vulnerability assessment of Barcza *et al.* (2013) assumes that adaptive capacity indicators have no substantial contribution to forest vulnerability.

Figure 5-1 and Table 5-1 summary the assessed forest vulnerability for the proposed classification of Carpathian forests:

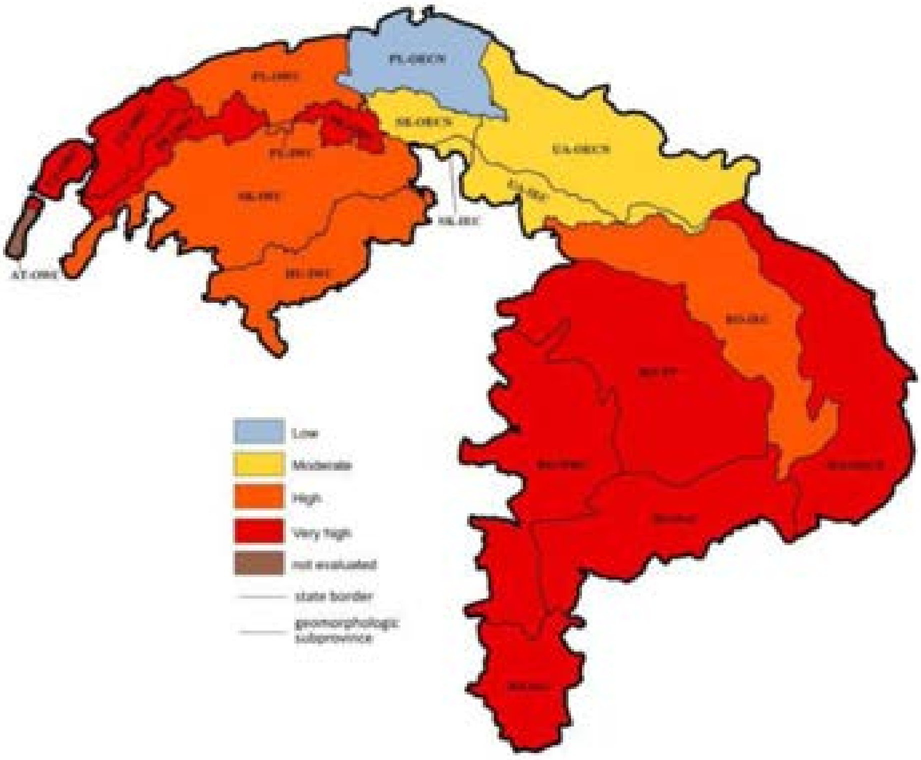


Figure 5-1 *Forest vulnerability per geographical sub-region of the Carpathians.*

Table 5-1

Forest vulnerability per geographical sub-region of the Carpathians.

Sub-region of the Carpathians	Forest vulnerability
Czech part of the Outer Western Carpathians	Very high
Slovak part of the Outer Western Carpathians	Very high
Polish part of the Outer Western Carpathians	High
Polish and Slovak part of the Outer Eastern Carpathians North, Slovak part of the Inner Eastern Carpathians	Low
Slovak part of the Inner Western Carpathians	High
Hungarian part of the Inner Western Carpathians	High
Ukrainian part of the Outer Eastern Carpathians North and the Inner Eastern Carpathians	Moderate
Romanian part of the Inner Eastern Carpathians	High
Romanian part of the Outer Eastern Carpathians South	High
Southern Carpathians	Very high
Western Romanian Carpathians	Moderate
Transylvanian Plateau	Very high
Serbian Carpathians	Very high

The assessment indicated a high level of forest vulnerability across the Carpathians. The high forest vulnerability in the Western Carpathians (CZ, SK, PL) is mainly related to the presence of highly sensitive secondary spruce forests, and to direct or indirect effects of drought (SK, HU). The main factors affecting high forest sensitivity in the Romanian and Serbian Carpathians were drought paired with related biotic damage, acting mostly upon broadleaved forests. High frequency of windstorms and subsequent bark beetle outbreaks were the main impact factors in mountain regions across the Carpathians, and mountain forests were thought of as highly sensitivity to these agents.

The assessment of integrated forest vulnerability indicates that most of the Carpathians has received high and very high scores of forest vulnerability to climate change. Only the Ukrainian Carpathians and Polish part of the Outer Eastern Carpathians were rated as moderate and low sensitivity. In case of the Polish part, low climatic exposure along with good forest structure and low biotic risk backed-up such ranking. The classification of Ukraine as moderate can be questioned. The facts supporting such classification were moderate exposure, and presence of mostly mountain forests which are not expected to face substantial drought in the future. In addition, no indicators of critical forest decline and effects on non-climatic stressors were reported.

5.2 Grassland Ecosystems

5.2.1 Current status

Grasslands are areas covered by grass-dominated vegetation with little or no tree cover. Various types of grasslands exist in Europe: from desert-like in the south-east of Spain, through steppes and dry grasslands, on to humid and generally damper grasslands and meadows, often on deeper and more fertile soils, lowland and montane, which dominate in the north and north-west (Silva *et al.*, 2008). Most European grasslands can be defined as 'semi-natural' because they have developed through natural processes over long periods of grazing by domestic stock, cutting and even deliberate light burning regimes; others may have originated from sown and grass leys aimed at producing forage for livestock. In almost all cases, they are modified and maintained by human activities, mainly through grazing and/or cutting regimes (Turbé *et al.*, 2010). Large areas of grassland have been lost in recent decades, causing severe fragmentation of the remaining habitat areas and a consequent drop in populations of certain species by as much as 20–50% across Europe (Silva *et al.*, 2008). Annex I to the Habitats Directive (HD) lists 45 grassland and meadow habitats of different types: natural, semi-natural, calcareous, dry, mesophile and humid; this reflects the high diversity of grasslands and the fact that most of them have been modified, created or maintained by agricultural activities (EEA, 2010).

Looking at the figures per biogeographical region 82.4% of grasslands in the Continental region have unfavourable conservation status, 8.8% is unknown and only 8.8% falls in the category favourable; looking at the Alpine region the distribution goes 68.4% unfavourable, 26.3% unknown and only 5.3% favourable; while the situation in the Pannonian region is the worst with 94.1% unfavourable, 5.9% unknown and no favourable grassland habitats (EEA, 2010). It is often difficult to distinguish the grassland habitat types from the agro-ecosystems (e.g. pastures, meadows, semi-natural grasslands). Unfortunately the conservation statuses of agro-ecosystems in the three biogeographic regions already mentioned, as in the rest of EU, are mostly unfavourable (80.7% in the Continental region, 68.8% in the Alpine region, and 91.6% in the Pannonian region).

In the Carpathian region identified grassland types include: natural grasslands (Corine land cover code 321) including HD Annex I types 6150 Siliceous alpine and boreal grasslands, 6170 Alpine and subalpine calcareous grasslands, and 6190 Rupicolous pannonic grasslands (Stipo-Festucetalia pallentis); semi-natural grasslands (Corine land cover code 321) including HD Annex I types 6230* Species-rich Nardus grasslands, on silicious substrates in mountain areas (and submountain areas in Continental Europe), 6240* Sub-Pannonic steppic grasslands, 6250* Pannonic loess steppic grasslands, and 62C0* Ponto-Sarmatic steppes Alkaline grasslands; semi-natural tall-herb humid meadows including HD Annex I types 6410 Molinia meadows on calcareous, peaty or clayey-silt-laden soils (Molinion caeruleae), and 6430 Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels; and mesophile grasslands including HD Annex I types 6510 Lowland hay meadows (*Alopecurus pratensis*, *Sanguisorba officinalis*), and 6520 Mountain hay meadows.

Almost a third of the Carpathians are covered by open and semi-natural habitats, predominantly grassland. Of the 133 habitat types identified by the Carpathian Ecoregion Initiative (CERI), no less than 76% are open habitats, many created by the activities of man over the centuries. These open habitats include the calcareous grasslands, fens maintained by traditional farming methods and the valuable and rare ’poloniny’ meadows. This unique grassland, occurring naturally at high altitudes,

was also partly formed by human activity: where the grazing cattle have destroyed the dwarf pine vegetation and forests. Grasslands such as the calcareous mountain grasslands, occurring in Slovensky Raj National Park in the Slovak Republic, are also incredibly rich in species. Over the generations, traditional shepherding systems in the Carpathians have created open plant communities such as those found on the gentle summer pastures of the Beskidy region; the grazing meadows in the valleys and mountain foothills; and the semi-open bush-meadow habitats created from grazing livestock in the forests.
Natural open habitats above the tree line, in the subalpine and alpine zones, are very limited in the Carpathians showing a typical 'stepping stone' pattern. They are, however, very important, supporting an unusually high number of endemic species. Traditional farming methods have shaped the landscape of the Carpathians and created a unique pattern of habitats, supporting a diverse variety of plant and animal species (Webster *et al.*, 2001).

Carpathian grasslands are among the richest grassland biotopes in Europe. Their high biodiversity value is a direct result of hundreds of years of traditional management and animal husbandry. The result of managed, domestic livestock-grassland interactions has been high species richness and the concentration of a high number of endemic and rare species on relatively small plots of land. The decrease in or cessation of human interventions (withdrawal of grazers, abandonment of meadows, etc.) in the Carpathian grasslands resulted in overgrowth of dominant species, degradation of mountain grassland habitats, and diminished diversity at the landscape/ecosystem, habitat and species levels. While collectivised agriculture was the principal cause of the abandonment of upland grasslands, the land remains abandoned even now, fifteen years after collectivisation ended, because it is no longer profitable for the average farmer to continue to utilize these upland grasslands given low market incentives and the current costs of time/labour and transport, as well as one-time costs associated with fencing and procuring additional animal (UNDP, 2005). There are however clear differences between the western and the eastern Carpathians: in the eastern Carpathians traditional land uses like grazing and herding are still occurring at a wide scale.

Ecosystem services
Grasslands are the basis for providing food from domestic, grazing animals, which, when they are traditional breeds, also conserve valuable genetic resources. The plants which make up the grasslands are also rich in genetic variability. Grasslands sequester substantial amounts of carbon, reduce soil erosion and assist in water management; furthermore, they have high aesthetic and cultural value. Semi-natural grasslands have developed under the impact of traditional agriculture and the landscapes they are part of may be valued as cultural heritage.

They also provide different regulatory services. Semi-natural grasslands harbour a diverse community of natural pollinators, while reduction of the area of such grasslands in landscapes and an increase in intensively managed land may lead to a decline in pollination services in agricultural landscapes.

Semi-natural grasslands within a matrix of agricultural landscape may also provide an important pest regulation service by regulating the population density of pests via biocontrol and resisting outbreaks of newly-introduced pests.

In principle, grasslands may play an important role in regulating climate changes through carbon sequestration. Accumulation of carbon in grassland ecosystems occurs mostly belowground and changes in soil organic carbon stocks may result from both land use changes (e.g. conversion of arable land to grassland) and grassland management (Vandewalle *et al.*, 2010).

All ecosystem services provided by grasslands show a degraded status since 1990, while three of them — wild foods, genetic resources and recreation — are still showing a negative trend (EEA, 2010).

5.2.2 Main impacts of climate change

Both grassland and forest habitats and species will be and are already affected by climate change through four main factors. These include changes in CO_2 concentration, in mean temperatures, in the dispersion of precipitation and in the occurrence of extreme weather conditions. The impacts of climate change will therefore result in combined effects of the before mentioned factors. Increased CO_2 concentration in itself would result in increased plant growth, however combined with an increase in mean temperature, decrease in precipitation and increase in the occurrence of extreme weather events will result overall in unfavourable conditions for vegetation (CEU, 2008).

Based on studies carried out in the Alps, mountain grasslands can tolerate 1-2°C increase of mean temperature without considerable changes if appropriately managed, however profound changes are forecasted in case of a temperature increase of 3°C or more, regardless the management method (Peters *et al.*, 2013).

Water scarcity is expected to cause the most serious problem for grassland ecosystem in the Danube River Basin. Droughts have already been affecting the Duna-Tisza köze, Tiszai-Alföld and Dunátúl regions of Hungary. Research on climate change impacts in the natural grassland ecosystems in the Carpathian-basin has shown that recovery after long lasting heat stress is much faster and much more effective in the case of plants grown in grasslands experiencing larger concentration of CO_2 than in ones grown under lower levels of concentration. In case of loess and sand grasslands, only a few years of increased CO_2 concentration led to changes in the relative proportion of grassland species, which is due to species' differing ability to acclimatize (CEU, 2008).

Grasslands will also be negatively affected by the climbing treeline. Climate change has resulted in warmer summer temperatures over the Carpathians, which are especially favourable for trees at upper elevations. A decrease of mountain meadow area and rise of treeline elevation has been observed from the early decades to the end of the 20th century, mostly by coniferous species at upper elevations (Martazinova *et al.*, 2009). Changes in species composition occur rather because of the appearance of 'new' species than because the intolerance of 'original' grassland species to climate change. As the changes proceed, species diversity may get higher in the first years (when the 'old' and 'new' species are present), but then it decreases as the new species taking over the habitats. Productivity is likely to follow the same pattern (Peters *et al.*, 2013).

BOX 5-1: Climate and treeline dynamics in the Ukrainian Carpathians (Martazinova *et al.*, 2009)

Climate change and treeline dynamics of the Ukrainian Carpathians during the 20th century were examined together with the changes in atmospheric circulation responsible for warmer summer and winter temperatures. Comparison of treeline positions in 1930-s and 2000 reveals a general rise of treeline elevation, mostly in places where the treeline is formed by coniferous species.
A decrease of mountain meadow area and rise of treeline elevation were observed, mostly by coniferous species at upper elevations. At locations with predominantly deciduous species there is little or no change. However, at ridges from the Beskids with predominant deciduous trees at treeline, colonization of meadow area by coniferous species was also observed. In many places the presence of sheep-holds obviously lowers the treeline position.

Vegetation types – plant communities – react differently to climate change. 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 (Peters *et al.*, 2013).

In summary, the main threats for grassland habitats are:

- Drought - which can reduce the productivity of grasslands and, therefore, their economic viability - potentially leading to changes in land management. Certain species are less drought tolerant than others; this can lead to their disappearance from grassland habitats and a change to those habitats in terms of other species entering to fill their niches. Changing species competition can lead to a reduction in resilience of ecosystems which l among other things leads to the invasion by alien species. Wet grasslands will be particularly susceptible to the effects of drought;
- Flood - unseasonal flooding of grasslands can result in the inundation and subsequent death of certain non-resilient/ resistant species, causing a change in the habit composition and a reduction in its resilience;
- Erosion - flooding and/or combined with extreme weather conditions, including drought and temperature increase can cause erosion to grasslands. Loss of topsoil will physically remove valuable grass and habitat and can allow niches for the establishment of invasive alien species, more aggressive and potentially damaging species, different habitat sites that do not contribute to the conservation value of the grassland;
- Temperature increase - impacting on individual species, species composition within habitats, etc., often with similar results to those described above;
- General deterioration to/loss of biodiversity – a.o. through the loss of habitat; habitat fragmentation and a lack of connectivity; changing land use practice.
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5.2.2.1 Impacts on generic grassland types

Observed impacts on generic grassland types were evaluated by the CarpathCC project (Barcza *et al.*, 2013). Although the assessment focused mainly on the grasslands of the Western Carpathians, it is expected that the detected trends are relevant also for the eastern and southern part of the Carpathians. The main conclusions of this assessment are:

- **Mesic semi-natural grasslands:** Only slight changes in species traits were noticed and even these can be attributed rather to land use changes and succession of abandoned grasslands. As mesic grasslands have a central position along the moisture and nutrient gradients, they can be assumed to be least sensitive to changes in climate characteristics in comparison to other grassland types;
- **Natural grasslands on calcareous bedrock:** Increase in species with higher Ellenberg indicator values[2] for temperature and continentality in the communities on calcareous bedrock indicate potential effects of climate change. High variation in temperatures between winters and summers, as well as between days and nights, typical for regions with continental climate, could occur in the Carpathian mountains in the future, and thus affect grassland communities towards higher representation of species with higher Ellenberg values for continentality.

  Similarly, decreasing occurrence of species with higher requirements for light could be a consequence of warming, because light conditions are influenced by competition of taller plants, therefore, one of the first effects of temperature increase will be the modification of competitive relationships between plant functional types (Guisan *et al.*, 1998; Theurillat *et al.*, 1998). Changes in climate that result in shortening of snow duration, and reducing snow depth and coverage may produce large changes in the C and N soil dynamics of alpine ecosystems (Williams *et al.*, 1998). Organic matter content, can be affected by climate change (directly or indirectly, qualitatively and quantitatively), resulting in changes in the main soil processes (humification, podzolization) and the nitrogen cycle (Theurillat *et al.*, 1998);
- **Natural grasslands on siliceous bedrock:** Comparison of the three periods (1925-1970, 1971-1990, 1991-2010) shows just small differences in distribution, ecology as well as species diversity of compared plant communities. No statistically substantial differences in altitudinal distribution of siliceous grasslands have been detected. Decreasing trends in the occurrence of species with lower Ellenberg indicator values for nutrients, temperature, soil reaction and light indicate effects of widespread nitrogen and phosphorus changes as a consequence of land use changes – for example decline of grazing in alpine areas. Decrease in soil reaction potentially indicates an impact of air pollution in Central Europe.

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[2] Ellenberg's indicator values were the first model of bioindication proposed and applied to the flora of Germany. The latest edition of Ellenberg's indicator values applies a 9 point scale for each of six gradients: soil acidity, soil productivity or fertility, soil humidity, soil salinity, climatic continentality and light availability.

A decrease in species richness may be connected with land use changes rather than with climate changes since from the middle of the 20th century, important changes occurred in traditionally managed meadows. Many traditionally livestock-grazed montane grasslands were either abandoned, leading to their disappearance through encroachment of shrubs, or higher selective pressure through sheep pasturing, which leads to a substantial decrease in the diversity of sensitive species and an increase in unpalatable clonal plants (Stampfli and Zeiter, 1999);

- **Semi-dry grasslands:** Semi-dry grassland communities and the species typical of semi-dry grasslands did not show any signs of sensitivity to recent climate change;
- **Dry grasslands:** There are no indications of change in environmental conditions related to climate change affecting the species composition. Neither dry grassland species nor dry grassland communities can be considered as sensitive to climate change. The indirect effects (increasing cover of woody species and mesophilous highly competitive species) could result in a decreasing number of specialist species well-adapted to dry and warm conditions. Despite the slight increase in overall species richness in these communities, the mesophytisation process might result in reduction of typical dry grassland specialists due to shifts in floristic and functional composition (Kovács-Láng *et al.*, 2000). As the dry grassland species are more resistant to climate-induced stress (summer drought, wind exposure, winter frosts, etc.), their gradual replacement by more mesophytic generalist species could induce further changes in the community composition;
- **Wet grasslands:** Changes in habitat conditions indicated by the measured (species richness and cover of the herb and moss layers) and calculated variables (Ellenberg indicator values) were significant in most cases, however, did not show an obvious trend of decrease or increase.

5.2.2.2 Impacts on specific grassland habitat types (European Habitats Classification)

To cope with the high complexity of grassland ecosystems, Peters *et al.* (2013) have selected 6 specific grassland habitat types to assess impacts and vulnerability. The selected grassland (and corresponding European Habitats Classification) are:

- 2 natural grassland habitat types: Siliceous alpine and boreal grasslands (6150), Alpine and subalpine calcareous grasslands (6170);
- 4 semi-natural grassland habitat types: Species-rich Nardus grasslands, on siliceous substrates in mountain areas (and submountain areas in Continental Europe; 6230*), Semi-natural dry grasslands and scrubland facies (6210), Lowland hay meadows (Alopecurus pratensis, Sanguisorba officinalis; 6510) and Mountain hay meadows (6520).

From the climate envelope modelling exercise, performed to model habitat distribution change, Peters *et al.* (2013) find that with respect to temperature change especially the natural grasslands are impacted, migrating upwards. The decrease in suitable habitats was most severe in the Southern parts of the Carpathians. Semi-natural grasslands are more exposed to land use change and abandonment, which is highest in the Romanian Carpathians. Climate change was found to have an overall positive effect on grassland productivity, however for more wet grassland type (6510) productivity could also decrease. The strongest productivity change was found in the semi-natural grasslands.

Although at present the current conservation status is generally good, Peters *et al.* (2013) show that conservation status could be substantially affected by future climate and land use change. This could in turn translate into severe effects on endemic species. Peters *et al.* (2013) links the occurrence of eight endemic species to specific grassland types, which showed a general decrease in both species abundance and distribution, suggesting that these endemic species could be under threat in the near future.

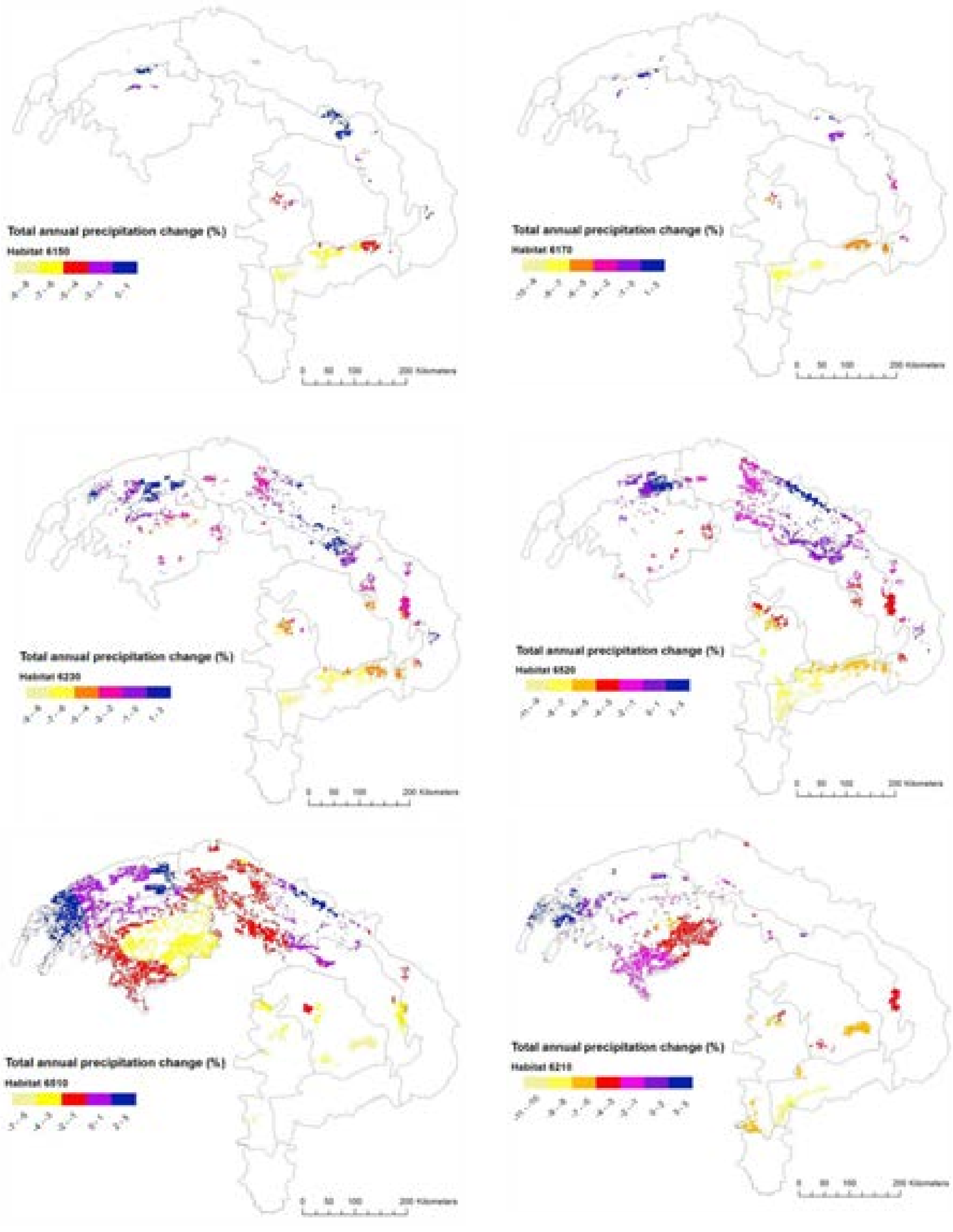

Figure 5-2 *Occurrence and total annual precipitation change (%) for the selected grassland habitat types.*

Three grassland types were considered most susceptible to climate change:

6150 Siliceous alpine and boreal grasslands

This grassland occurs within a large part of the Carpathians. It is of importance for the provisioning of different ecosystem services and acts as a habitat for some endemic species. Based on the literature review, climate change is considered a major threat to the future condition of this habitat especially in the long run. Climate impacts include: a potential change in species composition and distribution, an increase in productivity (Sârbu *et al.*, 2004).

6170 Alpine and subalpine calcareous grasslands

This grassland habitat has the highest number of endemic species within the Carpathians. Additionally this habitat type occurs in multiple countries with a high conservation status. Various impacts of increasing temperatures have been reported. One of the projected impacts is a progressive invasion of the subalpine grasslands by shrubs and colonizing arboreal species, such as Pinus mugo in the Alps (Dullinger *et al.*, 2003). In addition, higher temperatures will lead to a rising of the treeline and a loss of subalpine grasslands and the process will mainly affect calcareous habitats (Dirnböck *et al.*, 2003). Species at lower elevations will be able to invade high alpine communities (Grabherr *et al.*, 1994). The predicted changes are more likely to occur because of invasions by species, rather than because of the internal breakdown of communities, which usually are quite stable (Grabherr *et al.*, 2003). Alpine grasslands have a large inertia and can tolerate increases in temperature of up to 1-20°C, but drastic changes are predicted to occur if the increase is greater than 30°C (Theurillat *et al.*, 1998).

6230* Species-rich Nardus grasslands in mountain areas (and submountain areas in Continental Europe)

These grasslands are among the most common semi-natural grasslands within the Carpathians and important from a conservation point of view and for traditional pastoralism and other ecosystem services. The habitat also occurs in a lot of different countries. The optimum condition for the existence of Nardus grassland is low trophic status of the substrate. Hence it is believed that climate change should not cause disappearance of this habitat. However, it may lead to substantial changes in the species composition of different subtypes. Sub-types in transition from wet grasslands, and those occurring in high-altitude mountainous areas, especially chionophile types, are probably the most impacted. Pauli *et al. (2007)* reported a slow shift of the species of alpine communities into nival and subnival habitats. Experiments by Herben *et al.* (2003) in the Krkonoše (Czech Republic), demonstrated that the weather strongly influenced competition among species on mountainous Nardus grasslands.

5.2.3 Factors co-determining impacts and vulnerability

Agricultural intensification and land abandonment together provide two of the main pressures on biodiversity linked to grassland ecosystems at the EU level. Habitat fragmentation and conversion to biofuels or forestry represent growing threats (EEA, 2010). Abandonment of semi-natural grasslands, particularly species rich swards, generally has a negative impact on biodiversity and vegetation succession; resulting in a structural change from an open to a closed landscape and loss of forest-edge habitats which, in turn, has an impact on the fauna, for example, a decrease in habitat suitable for meadow birds (Veen *et al.*, 2009). Remaining grasslands often suffer due to intensive land use, irregular management or eutrophication. The increasing demand for biofuels places an additional pressure on grasslands (Vandewalle *et al.*, 2010). Changes to the breeds and species of domestic grazing animals and grazing intensification can change the quality of the sward and increase the possibility of invasion by weedy or alien species (Veen *et al.*, 2009).

The situation is not much different in the Carpathian region. Socio-economic changes in the recent years have led to profound changes for rural landscapes. Unemployment and poverty have accelerated rural decline in many areas leading to land abandonment, while traditional forms of forestry and agriculture are being replaced by more intensive methods. These trends are projected to continue (see Figure 5-3). Highly fragmented land-ownership structure is encouraging short-term forms of exploitation, such as heavy grazing at high altitudes and cropping on unstable slopes. Increasing outside investments coming into the region, political decentralisation and planning systems unable to cope with the new demands raise the chances of inappropriate development and threaten with habitats fragmentation (Webster *et al.*, 2001). Construction of roads and other infrastructure is leading to loss and fragmentation of habitats, threatening populations of flora and fauna and limiting their ability to adapt to climate change impacts (Peters *et al.*, 2013).

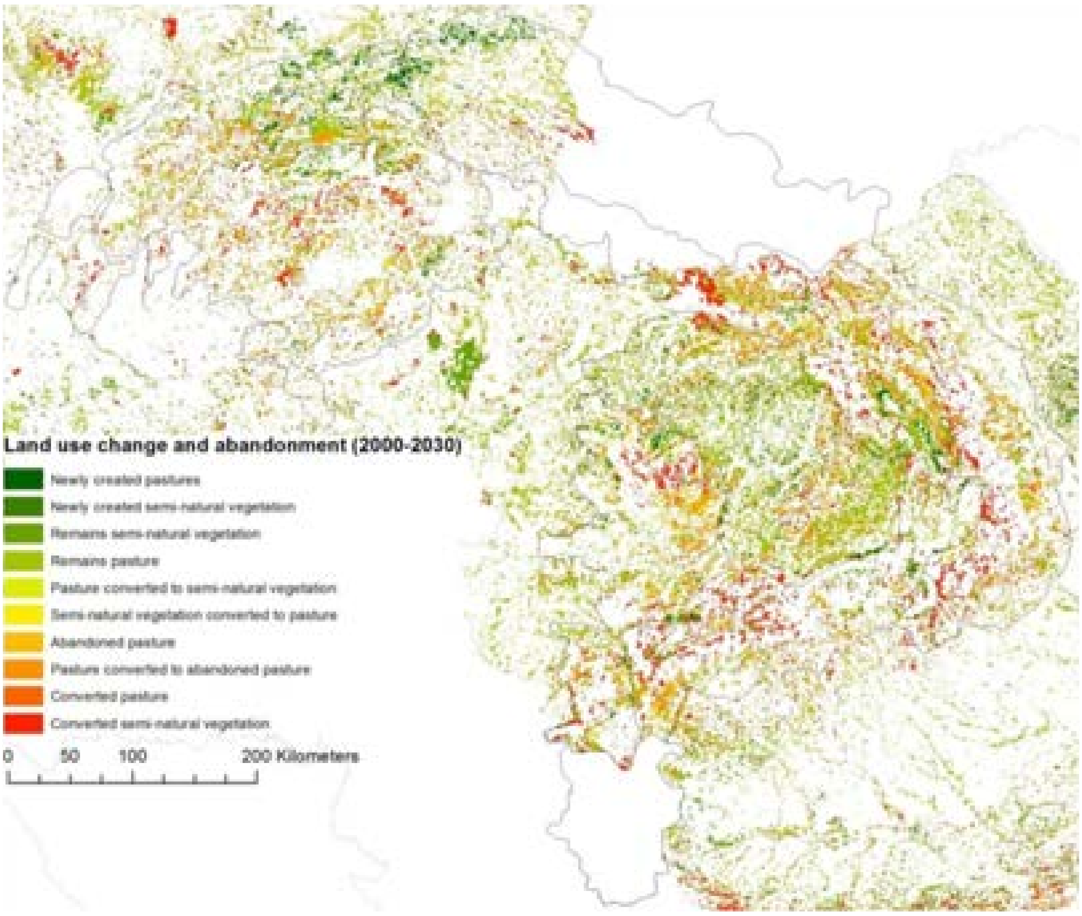

Figure 5-3 *Land use change and abandonment (Scenario B2, see (Peters et al., 2013)).*

Whilst the extensive pastoral culture which supports these habitats is still a vital part of life in Ukraine and Romania, changing lifestyles pose a threat to their future. In the western part of the Carpathians pastoralism and herding has nearly ceased to exist and vast tracks of semi-natural grasslands have been abandoned and are gradually taken over by forest cover. A reduction in agricultural subsidies, increasing economic costs and the transfer to a market economy has caused the abandonment of less productive or barely accessible grasslands. As a result, a trend towards forest communities is occurring and the majority of this unique ecosystem is being degraded. A lack of local interest in managing the land and additional intense pressure from the state forestry administration for large-scale afforestation of meadows, means that the open landscapes of the Western Carpathians are fast disappearing (Webster *et al.*, 2001).

Grassland habitat specific threats include (Peters *et al.*, 2013`, page 111):

- **Siliceous alpine and boreal grasslands (6150)**: inappropriate grazing practices; construction of infrastructure; changes in land use; negligible monitoring of pastures and invasive weed and tree species;
- **Alpine and subalpine calcareous grasslands (6170)**: Inappropriate grazing practices; construction of infrastructure (mainly ski resorts); changes in land use;
- **Semi-natural dry grasslands and scrubland facies on calcareous substrates (Festuco-Brometalia) (6210):** abandonment; change in land use; lack of or poor management; unregulated grazing; development of 'scrubland facies'; weeds invasion; agricultural intensification; airborne nitrogen deposition; construction of infrastructure; tourism; uncontrolled burning;
- **Species-rich Nardus grasslands, on siliceous substrates in mountain areas and submountain areas in Continental (6230):** over- or under- grazing; abandonment; forestation; sheepfolding; chemical fertilisation; tourism and recreational activities; soil erosion resulted from human activities; eutrophication; lack of adequate legal protection;

- **Lowland hay meadows (Alopecurus pratensis, Sanguisorba officinalis) (6510):** inappropriate grazing practices; construction of infrastructure; changes in land use; climate change; negligible monitoring of pastures and invasive weed and tree species;
- **Mountain hay meadows: negligible monitoring of pastures and invasive weed and tree species (6520);** lack of or poor management; afforestation; abandonment; conversion into pastures; inappropriate grazing practices.

Box 5-2: Endangered mountain grasslands in Slovakia

Meadows occupy 10.5 and pastures 22.7 per cent of agricultural land at present in Slovakia, however, there are differences in their distribution across the country. In lowland areas grassland is rare; on the other hand, some mountain villages are farming almost only on grasslands. The present state, extent, way of utilisation and the consequent species composition of the majority of semi-natural grasslands are influenced by the changes in farming practices since the 1950s. The following types of the mountain grasslands are at present endangered in Slovakia:

Wet submountain and mountain grasslands (Calthion)

Different communities of wet grasslands are relatively widespread in mountainous areas often in a mosaic with marsh and peat-bog meadows. They are distributed in mountain basins (e.g., below the High Tatra Mountains). They are unfertilised and regularly mown only in the areas with a lack of meadows of better quality (Orava, Kysuce). The larger part of these species-rich communities which form an attractive landscape has been changed into intensive grasslands.

Submountain and mountain oatgrass and yellow trisetum grasslands (Arrhenatherion)

They are distributed in all mountains and basins of Slovakia in altitudes between 400 m and 1,000 m on eutrophic and mesotrophic soils. The most species-rich mountain oat grasslands can be found on limestone on very steep slopes, on warm, protected sites with deeper soils. They are traditionally utilised unless they were afforested or lay fallow.

Rich mountain grasslands (Polygono-Trisetion,Calama-grostion arundinacea)

Fertilised, once or twice mown grasslands are very rare in the mountains of Slovakia. Their sites are reafforested, grazed or abandoned, and they have changed to high-herbaceous stands. They occur in typical forms only in limestone areas of the High Tatra (Belanské Tatry Mountains) at altitudes above 900 m. Grasslands with *Anemone narcisiflora* used to represent the grasslands of Slovakia which were richest in species and which have not been managed for a very long time.

Poor mountain grasslands (Polygalo-Cynosurenion)

Lower-stalked, flowering, unfertilised, once-mown meadows typical for sites poorer on nutrient in the entire Western Carpathians belong to the association Anthoxantho-Agrostietum. The presence of more species which indicate extensive management (species of warm and on nutrients poor sites, which have no chance to be successful in competition) is typical for the composition of these communities. Meadows of this group in nutrient-poor sites are changing into matgrass communities as a result of permanent extensive grazing.

Mountain matgrass meadows and pastures (Nardo-Agrostidion tenuis)

These are secondary (rarely primary matgrass and hair grass) grasslands of mountain to subalpine locations. Besides the species of mesophilous meadows there are also subalpine species. They are endangered by afforestation, intensification, grazing by large stocks of cattle, and abandonment. The regional types (e.g. East-Carpathians poloniny) and species-rich communities occurring on small areas are protected.

Subxerophilous meadows and pastures (Carduo-Brachypodion pinnati, Mesobromion)

These are extensive pastures on dry, shallow as well as deeper soils, on steep, south-oriented slopes on calcareous substrata, particularly rich in species. Currently they are not grazed and are very endangered by afforestation, overgrowing by shrubs and natural seeding. Groups of juniper often occur on these stands and therefore they are attractive a landscape point of view. The preparation of proposals for their management is necessary for maintaining the optimal species composition.

Source: Ruzickova, 1999

5.2.4 Policy (objectives) that can be affected by climate change impacts

No intergovernmental cooperation agreements exist that focus specifically on the impacts of or adaptation to climate change in the Carpathian region. At the same time, there are two areas of community policies related to environmental issues that can be connected to climate change adaptation. These are the European Union Directives related to water management (e.g. Water Framework Directive) and the Birds and Habitats Directives related to nature conservation (Natura2000) (CEU, 2008).

Based on the analysis for natural grassland types, Figure 5-4 shows land use and climate change impacts for Natura2000 grassland areas (Peters *et al.*, 2013). Although at present the current conservation status is generally good, Peters *et al.* (2013) show that conservation status could be substantially affected by future climate and land use change.

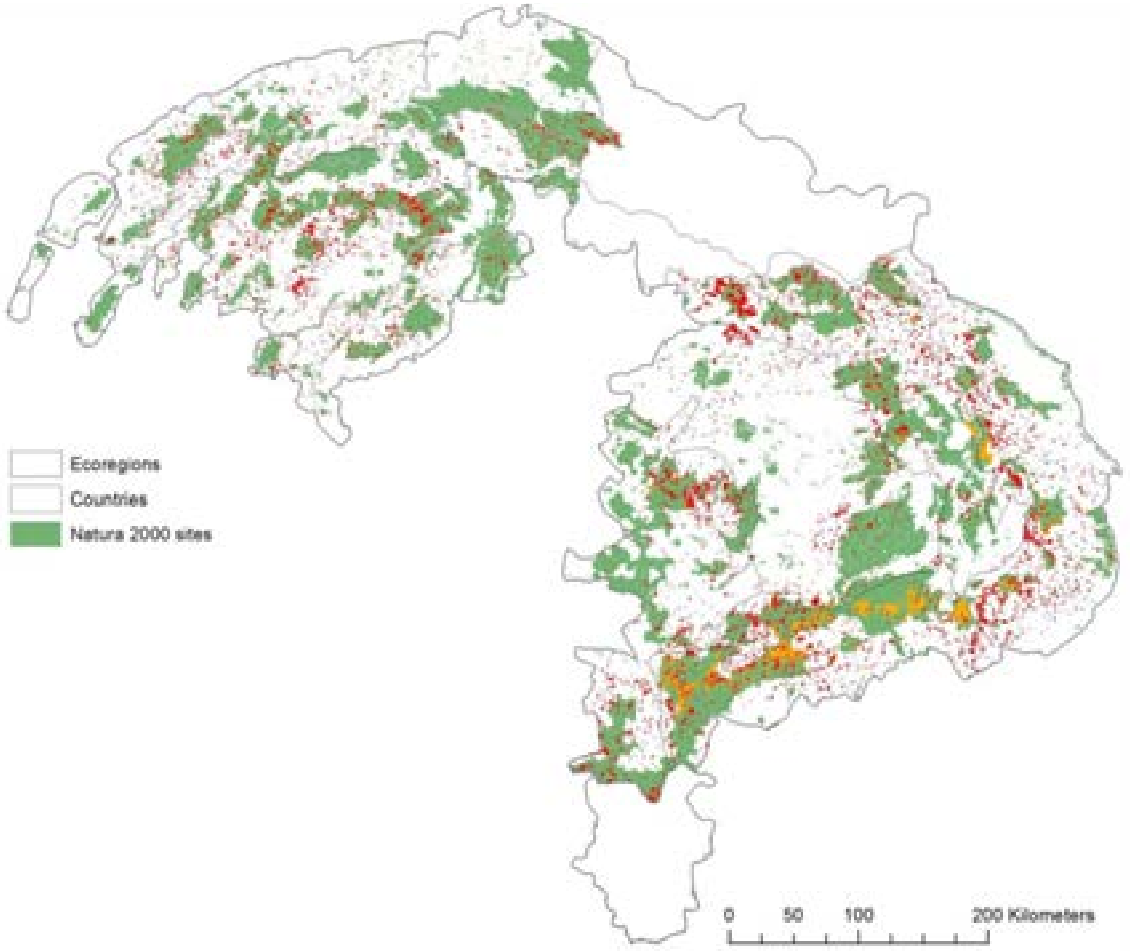

Figure 5-3 *Overview of areas expected to suffer from the effects of land use change, abandonment and climate change: areas sensitive to land use change and abandonment (red), natural grassland (yellow).*

5.2.5 Potential adaptation measures and strategies

The CarpathCC project evaluated the suitability of current management measures for grassland conservation in the future. Five main management measures are the most widely applied within the Carpathian, namely: grazing, abandonment, mowing, mulching and fertilization. Grazing and mowing was found to be of high importance to be maintained in the future. However, abandonment as a management measure for natural grasslands will be less suitable in the future due to forest encroachment and increasing timberline. Mulching and using fertilizers to increase the nutrient input is expected to be less suitable due to the presence of invasive species which thrive in higher nutrient conditions (Peters *et al.*, 2013).

Additional adaptation measures for grassland habitats can be summarised in four main groups: Increase connectivity, Protected areas, Adaptive management and Combating invasive alien species, and agro-environmental programs. Below these groups are described, with more details on the specific adaptation measures given in a table. Whereas these adaptation measures can be taken more locally, at a regional level we remark that linking different policies of nature conservation, river basin management and sustainable farming, possibly with the Ecosystem Services Approach as a supporting tool, could substantially strengthen the Carpathian region and its resilience towards climate change impacts. Regional cooperation platforms, like the Carpathian Convention, could be a critical vehicle to mainstream this in different countries. In addition, adaptation measures need to target both climate and non-climate factors as both have substantial interlinked impacts on grasslands. Adaptation measures can only be successful when also strengthening the socio-economic resilience of the communities living in the country side and when striving for an economically viable country side.

Increase connectivity - ecological networks have a very important role in climate change adaptation as they facilitate the migration of species in response to climate change. Populations should be able to move and migrate as the conditions become unsuitable.

Grasslands have a very specific and specialised fauna and flora. Whilst birds and butterflies and other flying animals, or those animals which are able to walk substantial distances have the potential to move between isolated or fragmented grasslands, many of the rarest species (particularly invertebrates such as butterflies and grasshoppers/crickets) have limited mobility. Plants disperse mainly by the transport of their seeds; by wind, water and in (via the digestive tracts) and on the bodies of grazing and to a lesser extent other animals.

Broadly (for illustrative purposes but not comprehensive) the measures that might be taken to increase the viability of populations within (what are now fragmented) grasslands seek to: protect, maintain and manage existing areas of high quality grassland; increase their connectivity; reinstate traditional management measures such as grazing by domestic stock within carrying capacity, seasonal flooding of floodplain grasslands, cutting and (where appropriate) burning regimes; and to restore or recreate degraded and lost grasslands. The CarpathCC project reviewed the cost of grassland restoration. For the "Restoration mowing and hay removal", average costs between 164 €/ha/a and 380 €/ha were reported in Slovakia, with costs reaching up to 650 €/ha if the cutting of trees and shrubs, and their removal is included. Hungarian cost data of Naturerdő Ltd can be interpreted as similar. The Bükk case is a factor higher, probably explained by the small scale of the restoration works. In Hungary costs are between 200 - 1700 €/ha, depending on the type of mowing activity and bush removal (Peters *et al.*, 2013).

Specific adaptation measures	Indirect issues/threats[3]
Protect, maintain and manage existing areas of high quality grassland. (This measure can be achieved through the identification/ designation of protected areas (see below) but also through the delivery of agri-environment funding that is targeted at the management and maintenance of traditional agricultural methods within targeted landscapes. One of the key threats to the maintenance of traditional agricultural management practice is provided by land abandonment which is linked to a range of socio-economic and demographic factors and changing cultural attitudes).	Land abandonment
Maintain traditional agricultural management. (For example, and linked to the above, provide incentives for the maintenance and re-introduction of floodplain management, transhumance grazing that results in the transport of seeds in or on domestic animals, etc.).	Changing land management practice
Increase connectivity. (Achieved through design and implementation of grassland corridors that link sites, provide 'stepping stone' habitats, remove barriers for dispersal, increase the size of existing grassland protected areas/grasslands of high-quality, create new and/or restore existing grasslands, seek to locate reserves close to each other. Mechanisms for achieving these aims will include targeting of agri-environment funding, spatial land use and management planning, etc.).	Socio-economic and demographic change
Study species dispersal across land use boundaries, gene flow, migration rates, historic flux.	Hydro Electric schemes (by creation of dams which alter floodplains, inundate areas of existing grassland, etc.)
Protect full range of bioclimatic variation.	
Study species distributions both current and historic.	
Broaden genetic and species diversity in grassland restoration and forestry. (Through ensuring that newly created grassland and forest areas have species mixtures that are representative of native/ natural forests and grasslands)	
Protect current and predicted future refugia sites. (It is possible to predict the future distribution of certain species based on their current biotic and abiotic requirements. Using this information it should be possible to identify existing as well as potential future sites - so-called refugia, where they will maintain viable populations in the context of a changing climate).	
Seek to ensure the representation of key species and habitats in more than one reserve. (In order to increase the chances of species and habitat survival).	
Evaluate the potential for species translocation/ reintroduction (and implement where feasible).	

Protected areas - the development and management of a protected areas network should be implemented in combination with increasing connectivity and allowing for adequate space for shifting of populations. Protected areas and other special sites for wildlife usually provide the core areas within any ecological networks approach – hence the strong link to ecological connectivity. Except for Ukraine and Serbia all countries have implemented the Birds and Habitats Directives and designated vast areas under the N-2000 network.

Measures that can be taken to increase the viability of protected areas in the context of climate change include: ensuring the maintenance of appropriate management practices (and the removal of inappropriate management), increasing their area, taking measures to protect their hydrological integrity, connecting them to other areas of similar habitat/other protected areas, providing sensitive management for the areas around them, etc. in relation to designating new protected areas it is important to consider the future range of certain rare and fragile species (and certain habitats) that may require protection in relation to changing distribution.

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[3] Note that climate change will bring indirect impacts to biodiversity through changes in socio-economic drivers, working practices, cultural values, policies and use of land and other resources. Due to their scale, scope and speed, many could be more damaging than the direct impacts, especially those that affect modified landscapes in which traditional agriculture is practised. There will be opportunities as well as threats for biodiversity and adaptation needs to address both.

Specific adaptation measures	Indirect issues/threats[1]
Strengthen the management of existing grassland protected areas. (There is a clear need to designate more/ provide better protection for existing grassland protected areas).	Land abandonment
Protect large areas of grassland (of sufficient quality), increase size of existing protected areas. (Area is a particularly important component in relation to the viability of protected areas of all kind, not least grasslands).	Changing land management practice.
Ensure appropriate financial and other resources are in place for the continued management and adaptation of protected areas. (e.g. Agri-environment schemes/ etc. are; also giving consideration to the needs in relation to a changing climate; etc.).	Inappropriate management practice, poaching, illegal activities, etc.
Create and manage buffer zones around reserves. (These zones can provide for the management of land and water in order to increase the resilience of the protected area in relation to the impacts of climate change, human activity, etc.).	Socio-economic and demographic change
Institute flexible zoning around reserves. (Specifically in relation to the land use practice that may/may not be allowed within buffer zones, etc.).	Hydro Electric schemes (by creation of dams which alter floodplains, inundate areas of existing grassland, etc.).
Locate reserves in areas of high heterogeneity, endemism. (The selection criteria for protected areas usually include a focus on identifying areas that include rare and/or endemic species, particularly important and/or rare habitats and ecosystems).	Ministry funding priorities.
Locate reserves at northern boundary of species' ranges. (Many species and, indeed, habitats predicted to move northwards in relation to their current distribution under the influence of a changing climate; there is much evidence for this already accumulating. It is therefore important to identify potential/ reinforce existing protected areas that will provide future living space for key species and habitats).	Wider Economic pressures.

Adaptive management – adaptation requires “adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities” (IPCC, 2007). Grasslands are generally ‘plagioclimax’ communities that have been traditionally maintained by: some form of grazing, cutting or burning regime that in pre-agricultural times may have been applied by wild animals or natural events; and since the development of agriculture by human activities.

Active management can therefore often be the only option for preserving grasslands under normal circumstances; in the context of changing climate conditions it is possible that such management regimes will therefore have to be adjusted in response to climate change. Without any management, grasslands are likely to succumb to colonisation by scrub, woodland and forests and even before this compensation will very rapidly lose a substantial component of their biodiversity interest through the dominance of coarse herbs and grasses which outcompete the more fragile and rarer species.

The maintenance and/or introduction/ reintroduction of low-intensity, sustainable grazing practices should therefore be encouraged where native species are adapted to it (it is only where the soil is extremely thin and infertile, or above the tree line in mountain ecosystems that grasslands may be maintained without a degree of management intervention). Heterogeneity of management should be maintained at the landscape level and mimic grazing patterns of native herbivores/ traditional domestic grazing breeds. Eventually e.g. Grazing Management Plans should be created that are adapted to the characteristics of individual or groups of pastoral units. Managers can influence the composition by applying different grazing regimes: stock type (cattle, sheep, etc.), grazing periods (season of grazing), stocking rates, duration of grazing (time of which grazing is allowed) and grazing system (sequence and patterns of grazing events) (Peters *et al.*, 2013`, page 183).

Specific adaptation measures	Indirect issues/threats
Introduce/maintain harvest schedules, grazing limits, incentive programs that reflect management needs/ flexibility of management in relation to climate change. (Most effectively through targeting and delivery of agri-environment funding schemes)	Land abandonment
Practice intensive management in target areas. (In order to secure the long-term future of specifically identified/ located populations of particularly important species (and habitats). Not likely to be achieved by the general application of agri-environment funding, but through more specific nature conservation related funding that can be targeted at species/location in question).	Changing land management practice.
Practice adaptive management. (One aspect of this will be the tailoring/ flexibility set out in the first bullet point above; further efforts will be required in order to: 1) reduce sources of harm not link to climate; 2) use existing biodiversity legislation and international agreements to enable effective action now while working with policymakers to remedy any potential shortcomings; 3) apply measures already mentioned in section is above (e.g. seek to conserve the widest range and ecological variability of habitats and species in order to increase the chances that species and current habitat becomes inhospitable will be able to spread locally into newly favoured habitat; maintain existing and establish new ecological networks; take proper action to control spread of invasive species - see below; aid gene flow between populations; and so the role of species translocation and ex situ conservation and: develop institutional capacity).	Inappropriate management practice, poaching, illegal activities, etc.
Promote appropriate conservation policies that engage local users and promote healthy human communities. (Policies within the strategic documents should be 'climate proof' and provide the basis for adapting to climate change, in this case specifically in relation to biodiversity).	Socio-economic and demographic change
Adopt long-term and regional perspective in planning, modelling, and management. (Linked to a required cultural shift in relation to working positively towards the future of potentially different circumstances, learning from experience, and sharing information more widely within and between organisations, whilst retaining consistent objectives).	Hydro Electric schemes (by the creation of dams which alter floodplains, inundate areas of existing grassland, etc.).
Manage for flexibility, use of portfolio of approaches, maintain options. (As above).	Ministry funding priorities.
Create culturally appropriate adaptation/management options. (As above).	Wider Economic pressures.
Create education programs for public about land use practices and effects on climate change.	Cultural attitudes in relation to change and change management.
Maintain natural disturbance dynamics of ecosystems. (Healthy ecosystems are more resilient and able to deal with external change and disturbance).	
Practice proactive management of habitat to mitigate warming. (It is clear that 'pre-management' and prior protection of habitat in relation to predicted impacts of climate change will be more effective as an annotation tool than *post hoc* actions).	
Start strategic zoning of land use to minimize climate related impacts. (Linked to comments already made above).	

Combating invasive alien species – Invasive Alien Species (IAS) are non-native species whose introduction and/or spread outside their natural past or present ranges pose a threat to biodiversity. They occur in all major groups, including animals, plants, fungi and micro-organisms, and are considered to be the second most important reason for biodiversity loss worldwide (after direct habitat loss or destruction).

Invasive species can cause great damage to native species by competing with them for food, eating them, spreading diseases, causing genetic changes through inter-breeding with them and disrupting various aspects of the food web and the physical environment.

Their establishment causes habitat degradation and species loss (decrease of biodiversity). Climate change often facilitates their spread even more. Special attention should be paid to the sources of invasion like grass/crop seed mixtures and disturbance.

Specific adaptation measures	Indirect issues / threats
Mitigate other threats. (For instance, see above, and specific references to the impact of climate change on habitats and species that may allow the establishment and spread of IAS).	*Land abandonment*
Develop an IAS strategy for the region. (In order to: anticipate surprises and threshold effects i.e. major extinctions or invasions; set out desirable actions and cross boundary collaboration; provide for early-morning strategies, including public awareness campaigns; etc.).	Changing land management practice.
	Inappropriate management practice, poaching, illegal activities, etc.
	Ministry funding priorities.
	Absence of strategic approach.

Agro-environmental programmes - The task of the agro-environmental programmes is to harmonize relations between the production of food and the conservation of the environment. They do so by issuing compensation payments for environmental friendly management or for economic loss because of nature conservation restrictions.. A parallel goal is to contribute towards the maintenance of village communities. Through the support of climate friendly management these programmes can be a carrier of climate change adaptation. The CarpathCC project has reviewed current subsidies on agro-environmental programmes in the Carpathians, focussing on grasslands (Peters *et al.*, 2013`, page 180-187). Most measures relate to mowing and grazing. A combination of mowing and pasturing is the traditional method employed on semi-natural grasslands in the Carpathians. Its continuation is highly recommended, because mowing as a non-selective method of biomass removal promotes different species from selective grazing. Despite frequent mowing being the practice recommended for grasslands of high nature value, the traditional method of hand mowing is less and less practised due to high costs of labour. Agro-environment programmes are critical to maintain and enhance the biodiversity and ES of (semi-)natural grasslands. Below we summarise key implementation mechanisms, measures and financial information.

Specific adaptation measures	Financial details
Agro-environmental measures (Pillar II): High Nature Value Grassland Traditional farming Medicinal and aromatic plants Important grassland for butterflies	 124 (€/ha, Romania) 58 (€/ha, Romania) 270 (€/ha, Romania) 240 (€/ha, Romania)
Mowing (grassland management), depending on the timing of cutting, its distribution, use of machinery, shrub removal	Subsidy 77-116, 400 for hand mowing (€/ha/yr, Hungary)
Grazing (grassland management), depending on stock type (cattle, sheep, etc.), grazing periods (season of grazing), stocking rates, duration (time of which grazing is allowed) and grazing system (sequence and patterns of grazing events)	Subsidy 48-97 (€/ha/yr, Hungary)
Agricultural land inside conservation areas eligible for Natura 2000 payments	95 (€/ha/yr, Slovakia)
Management scheme consisting of limited use of fertilizers and pesticides, special mowing dates and a special regime of grazing	Subsidy 60-190 (€/ha/yr, Slovakia)

5.2.6 Integrated assessment of grassland vulnerability

Carpathian grasslands are of great importance for both nature conservation and local population. Most are the result of traditional farming practices and of thousands of years of human interaction with land and nature. Semi-natural grasslands are more agriculture-oriented than natural grasslands. Extensively used (semi)-natural pastures and meadows deliver a whole range of ecosystem services: high quality food, clean water, mitigation of climate change, biodiversity conservation, recreation, tourism and important aesthetic and cultural non-use values.

Under recent conditions management regimes have more impact on grasslands in the Carpathians than climate change, however those regimes influences the responsiveness capability of grasslands to climate change. In addition, long established and stable grassland communities (e.g. mountain hay-making meadows) are more tolerant to climate change than grasslands with short history. Maintaining therefore appropriate – usually traditional – management methods is vital. Adaptation measures can only be successful when also strengthening the socio-economic resilience of the communities living in the country side and when striving for an economically viable country side.

Results show that impacts on grasslands are determined by both altitude and geologic substrate. E.g. species on calcareous substrates are more susceptible to climate change due to their dependence on soil type. In alpine and subalpine calcareous grasslands, beyond the general measures for minimizing the effects of climate change, little more can be done beyond establishing a network of monitoring sites at the most representative points in the alpine mountains. The habitat is therefore noted as highly vulnerable to climate change. Conversely, for species-rich Nardus grasslands in (sub)mountain areas more opportunities exist for grassland management and this habitat type is assessed to have a moderate vulnerability to climate change (Peters *et al.*, 2013). Table 5-2 summarises threats, adaptation possibilities and vulnerability for key habitat types.

Table 5-2

Overview of threats, adaptation possibilities and vulnerability for key habitat types. – indicating a strong negative response, - a mild negative response, +/- no clear response, + positive response, ++ highly positive response.

Natural grasslands	**Climate change related**			**Land use change + abandonment**	**Other threats (not related to CC and LUC)**	**Adaptation**	**Vulnerability**
	Productivity change	**Species composition +abundance**	**Change of occurrence / distribution**				
Natural grasslands							
Siliceous alpine + boreal grasslands (6150)	+	-	-	-	Invasive weed and tree species; construction of infrastructure	-	-
Alpine + subalpine calcareous grasslands (6170)	+	-	-	-	construction of infrastructure (mainly ski resorts)	--	--
Semi-natural grasslands							
Semi-natural dry grasslands on calcareous substrates (6210)	+	+/-	+/-	--	Weeds invasion; agricultural intensification; airborne nitrogen deposition; construction of infrastructure; tourism; uncontrolled burns	-	-
Species-rich Nardus grasslands in mountain areas (6230)	+	-	+/-	--	Chemical fertilisation; tourism and; soil erosion, euthrophication; lack of adequate legal protection	+	+
Lowland hay meadows (6510)	-	-	+/-	--	Invasive weed and tree species; construction of infrastructure; negligible monitoring of pastures	+	+/-
Mountain hay meadows (6520)	++	+/-	+/-	--	Negligible monitoring of pastures; invasive weed and tree species; afforestation	-	+/-

5.3 Wetlands and aquatic ecosystem

5.3.1 Current status

Wetlands in the Carpathians are mostly small-scale. Within a large range of wetland types (51 habitat types just in Western Carpathians), fens dominate the landscape (Šeffer *et al.*, 2010). Wetland ecosystems are very fragile and sensitive to natural as well as anthropogenic pressures. Over 75% of the upper floodplains in the Carpathians have been converted for farming or were lost due to hydrotechnical or tourist infrastructure development (CEU, 2008). The ones surviving to our days are in inadequate state and under poor protection: from 5200 ha eutrophic marshes, 1800 ha oligotrophic marshes, 275 000 ha open stagnant waters in Romania (53% of the territory of Carpathians), only one site is under international protection of Ramsar Convention.

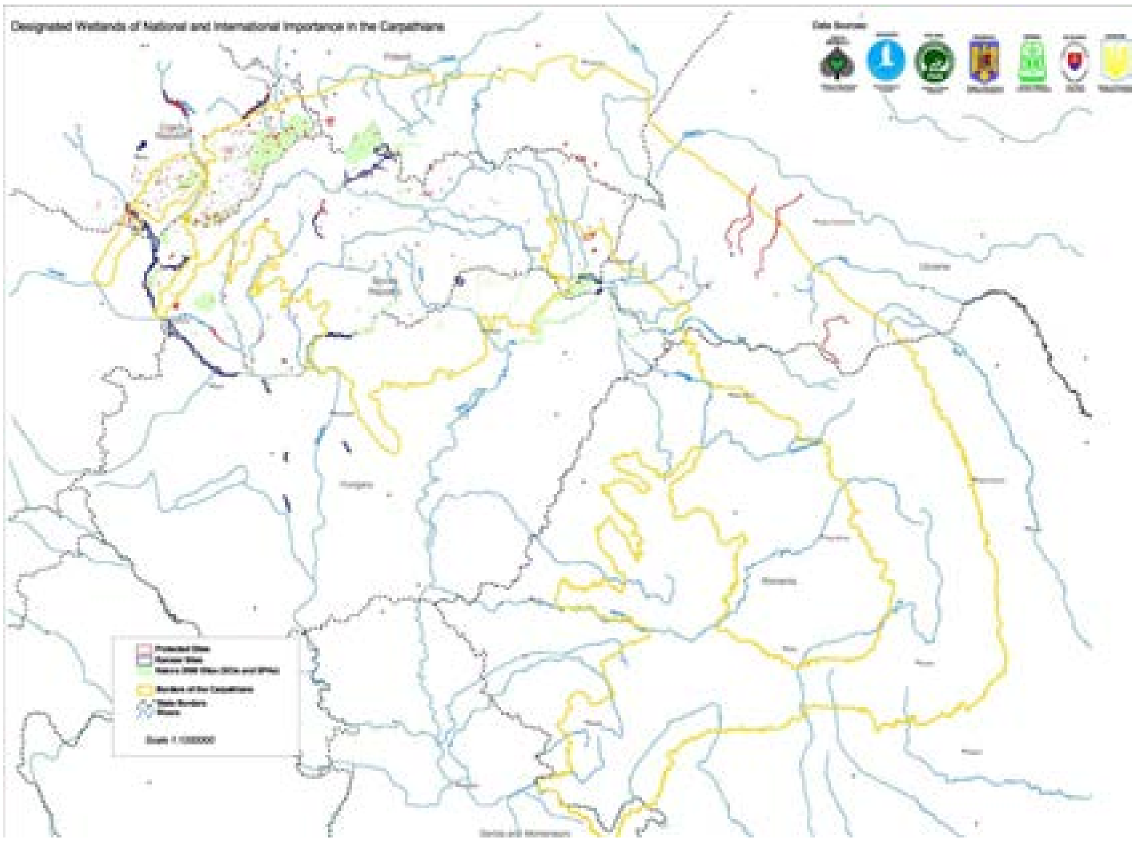


Figure 5-4 *Designated wetlands of (inter)national importance in the Carpathians.*

5.3.2 Main impacts of climate change

Freshwater ecosystems have been identified as the ones being most severely impacted by climate change, with the highest number of species under threat (Bates *et al.*, 2008). Under 3-4°C of warming, 85 per cent of all remaining wetlands could disappear (UNDP, 2005). The most likely impacts related to surface water resources will include more frequent flooding, longer periods of drought, an increase in water temperature, which will in turn indirectly contribute to deteriorating water quality, limitation of ground water recharge, spread of invasive species, disconnection of functional habitats, as well as harming overall river integrity (CEU, 2008). Chapter 4 summarised impacts on water resources in more detail.

Drawing from research done across Europe, we can think of the scale of changes awaiting wetlands in the Carpathian region. Increased air temperatures are likely to have a drying effect on many wetlands, unless increased precipitation compensates for evaporation. If precipitation declines and groundwater is extracted for human needs, shallow and ephemeral habitats, such as depressional wetlands or wetlands in arid areas that often harbour rare species, could be lost entirely (Gitay *et al.*, 2001). Small, temporary wetlands are the most numerous types of wetlands in many landscapes, and are often used by more species than permanent ponds (Gibbs, 1993; Semlitsch *et al.*, 1996; Semlitsch and Bodie, 1998). The drying and loss of wetlands would reduce not only the number and size of available ponds, but also increase inter-pond distance (Gibbs, 1993; Semlitsch and Bodie, 1998), lowering the chances of amphibian recolonization, since adult frogs are generally only capable of travelling 200-300 m (Sjögren, 1991). Drying and loss of wetlands would also reduce habitat connectivity on a regional scale, endangering migrating birds that depend upon a network of wetlands along their migration route. According to the projections, the survival rate of most bird species in Europe is likely to improve due to the temperature increase in winter, but this might not be the case in southeast Europe where lower precipitation levels might endanger existence of wetland ecosystems and populations of water-fowl birds as such. For example, in Serbia there are 253 nesting species (84% of the total birds species present in the Balkans), and all in all there are 340 bird species in the Danube Delta, including globally important populations of red-breasted geese and Dalmatian pelicans that are dependant on the wetland ecosystem (CEU, 2008). Overall, a drier climate is likely to lead to contractions and loss of wetland habitat, as well as increased habitat fragmentation.

The direct impacts on wetlands and aquatic species include:

- Changes in ecosystem balance - with some species increasing in numbers and inhabiting new and larger areas, and others species decreasing;
- Habitat shift - with changes in temperature and rainfall patterns some species will move to new areas => unpredictable ways of carbon dioxide concentration changes, changes in the interactions between species and the low availability of a suitable habitat;
- Changes in the genetics of species, which will occur as they evolve in response to the changing environment and changes in other species.

There were attempts to identify potential impacts of climate change on wetlands on European, country (HU, RO) or catchment scale (Danube, Tisza) but no study was found specifically for Carpathian region. According to an overview done on European scale by Research Unit Sustainability and Global Change (Center for Marine and Atmospheric Sciences, Hamburg University) there is a lack of studies addressing species–environment and cause–effect relationships in wetlands, for example water level requirements of species, that would enable assessing the potential scale of change in biodiversity composition; interrelations between drivers, pressures, and wetland responses.

There is a number of projects looking at climate change impacts on aquatic ecosystems but only one (REFRESH) will go into detail of climate change impacts on wetlands. Project REFRESH runs from 2010 till 2014 and will develop an on-line decision support system integrating impacts of climate change and land use change to enable freshwater managers to design cost-effective restoration programmes for freshwater ecosystems.

5.3.3 Factors co-determining impacts and vulnerability

In most cases it is hard to identify what has bigger impact on state of wetlands - climate change or land use change. Trends in the human use and status of European wetlands are strongly related to historic patterns of land use change. Between 1950 and 1980 many wetlands were drained in both western and eastern Europe and converted into forests (68%) and agricultural land (10%) (Silva *et al.*, 2008). However, there are no reliable European statistics on wetland loss (Harrison *et al.*, 2010). These large decreases in the surface area of wetlands also decreased their ability to provide and store freshwater and regulate the climate during this time.

5.3.4 Policy (objectives) that can be affected by climate change impacts

The Water Framework Directive identifies one of the environmental objectives as an obligation to “prevent more than ‘very minor’ anthropogenic disturbance to the hydro-morphological condition of surface water bodies at High Ecological Status. This includes the condition of the riparian, lakeshore or inter-tidal zones, and hence the condition of any wetlands encompassed by these zones. This is necessary to achieve the objective of preventing deterioration in water status” [Article 4.1 (a) (i); Annex V 1.2]’. Recognising an important role that wetlands play in water quality regulation and ground water recharge, climate change can be seen as a potential threat to stability of water supply. Wetlands will form part the ‘basic measures’ [Article 11.3] that are the minimum necessary to meet the environmental objectives of the Directive.

Resolution of Ramsar convention Conference of Parties calls upon Contracting Parties to “manage wetlands so as to increase their resilience to climate change and extreme climatic events, and to reduce the risk of flooding and drought in vulnerable countries by, inter alia, promoting wetland and watershed protection and restoration”.

The Carpathian Wetland Initiative and Science for Carpathians (S4C) are two international bodies that try to coordinate research agenda in the region. In the S4C research plan for 2010-2011 climate change research needs are identified as follows: “(1) identify the magnitude and character of climate change in different parts of the Carpathians, and to (2) characterize its impacts on environment and human activities. Therefore, (3) joint studies using the same time scales and methodology are needed”. Both the Carpathian Wetland Initiative and S4C underline that it is the basic research and system understanding that is lacking, not to mention projection of impacts.

5.3.5 Potential adaptation measures and strategies

Adaptation strategies for wetlands are closely linked to adaptation measures aimed to make hydrological systems more resilient. Unpredictability of discharge patters is one robust finding of climate change research. This calls for a more robust water system with increased retention capacities in upstream parts of the basins and especially in the higher altitudes. Maintenance and restoration of wetlands in the higher altitudes play an essential role in increasing the retention capacities and in reducing the impacts of droughts and access precipitation.

In a situation of high uncertainty, recommended adaptation measures are the ones following ‘no-regrets’ strategy. For example, the Danube River Basin Management Plan (DRBMP) suggests increasing ecosystem resilience through floodplain restoration - recreating wetlands will restore regulatory and supporting functions, enhance natural water purification, mitigate effects of droughts and floods, etc. Examples are floodplain restoration to recreate wetlands that can serve as water buffers in times of floods and droughts. Also, installing fish passes will allow fish species to freely adjust their feeding or spawning range when environmental conditions change. In the places where restoration is difficult, it is highly recommended to reduce external non-climate pressures: land use changes, over-fishing, invasive species and pollution. Improving connectivity between the water bodies can help species/communities move their ranges, as well as preserve habitat heterogeneity and biodiversity, which can provide genetic diversity for successful adaptation. Other adaptation measures include:

- Reduce external non-climate pressures through a.o. smart land use planning, recycling of water, diversifying sources of income generation;
- Help species/communities/economies move their ranges: improve connectivity within & between water bodies;
- Develop separate plans for species /communities/economies that cannot easily shift ranges; Protect physical features rather than individual species;
- Implement an adaptive management plan to mitigate climate-driven hydrological changes.

5.3.6 Integrated assessment of wetland vulnerability

Investigations of wetland habitats vulnerability to climate change focused on wetland types protected by the network of NATURA2000 (Barcza *et al.*, 2013). The main conclusions are the following: (i) the most vulnerable wetland habitats are peat lands, because of their limited plasticity towards climate fluctuations, and their sensitivity to human activities and changes in land use; (ii) High mountain wetland types are also considered highly vulnerable to climate change because of their restricted dispersal and low resilience; (iii) less vulnerable are halophytic habitats and some water and river banks habitats (salt meadows, steppes and marshes). These habitats posses some plasticity towards climate fluctuations, but they are highly sensitive to human activities and changes in land use; (iv) The lowest vulnerability was detected in habitats depending on floods, habitats on stands with fluctuating soil moisture, for subterranean wetlands and for some river bank and water habitats. They can be thought of as highly plastic and able to adapt even to extreme fluctuations in climate. Human intervention may represent an important threat also in this case.

6 Ecosystem based production systems: impacts of climate change threats, adaptation & vulnerability

6.1 Forestry

6.1.1 Current status

Wood harvesting and exploitation of the forests in the Carpathians have a long history. The forests of the Carpathians are now a patchwork of deciduous, coniferous and mixed stands. The largest forest complexes are found in the Eastern Carpathians. In the Western and Southern Carpathians, substantial areas were deforested and converted to other land uses. In the foothill areas, forests are small and scattered and the landscape is dominated by other types of land use (agriculture, residential, infrastructure, etc.).

Forestry remains an important economic sector in the Carpathian countries, particularly in Romania, Slovakia and Ukraine, although there are substantial national and regional differences. Changes observed recently are in three main directions: the attitude of people to forest use, privatization, and the conservation status of forests. For the latter part of the 20th Century, Carpathian forests were owned and managed by the State. Substantial restructuring of the sector is taking place, including the fragmentation of ownership, affecting forest exploitation. State owned forests are returned to their original owners in the process of ‘restitution.’ Whereas small- and medium-sized forest properties used to be a part of the pattern of rural areas, this traditional pattern has in most cases by now been lost. It is suggested that pressures increase to clear-cut section of forest for a rapid economic gain. As a result various national forest administrations are promoting 'good forest management' (CERI, 2001; Csagoly, 2007; Kozak *et al.*, 2007; Kuemmerle *et al.*, 2007; CEU, 2008)

6.1.2 Main impacts of climate change

As climate change is expected to strongly influence forest ecosystems in the Carpathian region (See Section 5.1), substantial implications can also be expected for forest production. This can have substantial economic impacts, as forestry plays an important role in the economies especially of the areas in mountainous regions (CEU, 2008). In central Europe, a change in the type of impact (positive and negative) in terms of the net primary productivity of forests is expected during the course of the century (IPCC, 2007). The negative impacts of climate change can lead to potential losses in quality and quantity of raw materials for the timber industry in the region, as well as to the deterioration of other forest functions listed above. Further negative impacts of climate change on forests include droughts leading to increased water stress, which in turn result in decreased natural and economic yields of natural growth forest systems (beech, hornbeam-oak, oak groves) (Führer and Mátyás, 2005). Recent projections suggest a loss of the present value of European forest land in year 2100 between 14 and 50% (Hanewinkel *et al.*, 2013), which is particularly worrying for the sensitive economies of the Carpathians.

Apart from negative impacts, climate change can also contribute to increased forest production under specific circumstances. Increasing mean temperature combined with increased CO2 concentration speeds up photosynthesis in most temperate tree species (Tasnády, 2005). However this only occurs if water supply, light and nutrient supply does not emerge as a limiting factor. Analysis of trends in tree growth occurring in the past few decades in Hungary indicate that increases of mean annual temperature could positively have affected growth of the beech, sessile oak and Turkey oak species. At the same time water availability is soon expected to act as a limiting factor to this acceleration of tree growth (Somogyi, 2008).

6.1.3 Factors co-determining impacts and vulnerability

Natural disasters (excessive floods, storm induced tree falling and catastrophic landslides), spread of new or formerly uncommon diseases and pests that can damage forests. Land use management.

6.1.4 Policy (objectives) that can be affected by climate change impacts

Specific national objectives for timber production and forestry output can be impacted. Apart from the timber industry, forests have a number of other economic and crucial ecological functions. These include recreation, conservation of biodiversity, protection of water and soils, and contribution to global carbon circulation.

6.1.5 Potential adaptation measures and strategies

As forests are managed intensively in Europe, there is a wide range of management options, including changing the species composition of forest stands (IPCC, 2007). Adaptation options for forests in general include changing the species composition of forest stands, development of advanced systems of forest inventories and forest health monitoring (IPCC, 2007) (see also Section 5.1.5). This requires a shift from traditional timber production-oriented management towards an adaptive risk-responsive management. Forestry practices need to be adapted to the changing abiotic and biotic factors that are expected to occur as a result of climate change. Increased wood production can be achieved by preservation of the microclimate through the use of native, relative and pioneer species, and forest renewal and cultivation practices. In new forest plantations it is crucial to choose tree species that will be suitable to the expected changes in climatic conditions (such as increasing temperatures and decreasing precipitation) through the full lifespan of the trees. Planting tree species with shorter life spans rather than tree species that need more time to reach full development (such as oak, which needs 80-100 years) provides more flexibility in adapting to changes in climate without serious losses in timber production. Changes in tree species composition supporting forests' drought tolerance need to be promoted. At the same time, the share of vulnerable Norway spruce forests needs to be substantially reduced. Existing forest stands can be made more resistant by increasing the number of species in the stand in this way increasing biodiversity, and by deploying native species (keeping in mind their suitability for the expected climactic conditions through their whole life span) (CEU, 2008). Specific adaptation options for mountain forests include those mentioned in Section 5.1.5.

As a result of greater danger of forest fires, the need for fire protection measures will increase. Since in the Carpathian Basin drying of the climate is already being experienced, preservation and potential increase of forest stands is a complex challenge. It is possible to address this challenge through a combination of measures which contribute to the preservation of the microclimate of forests (which includes preservation of favourable water and humidity levels) on the one hand, including the use of native, relative and pioneer species as well as forest renewal and cultivation practices on the other hand (Tasnády, 2005).

6.2 Agriculture

6.2.1 Current status

Despite contributing a minor share to the GDP of the Carpathian countries (highest is in Serbia – 15%, then Romania and Ukraine - 7%, 2007), agriculture plays an important role on a regional scale. Agricultural lands constitute 39.8% of the territory of the Carpathians, providing income for about 20% of local population (Ruffini *et al.*, 2008). In different countries, due to historical developments, the share of the population working in agriculture varies substantially: from 2,3% in Slovak mountain regions to 47.7% and 50% in Romanian and Ukrainian parts respectively.

Table 6-3

Significance of agriculture in various Carpathian countries (SARD-M, 2008).

Country	Territory of Carpathians as part of territory of a country, %	Agricultural lands in the Carpathian region, %	Population employed in agriculture in the Carpathians, % from total in the region
Slovakia	69.8	41.2	2.3
Romania	29.4	37.6	47.7
Czech Republic	12.2	53.9	11*
Republic of Serbia	9.7	56	17.3*
Hungary	7.3	59	4
Poland	6.2	42	n/a
Ukraine	3.1	21.3	50

*) from country population

Since the fall of the Iron Curtain, the structure of the agricultural sector in the Carpathians is being reformed: overall crop and livestock production has been reduced and 15-20% of cropland has been abandoned and became fallow (Kuemmerle *et al.*, 2007). Only in the lower parts of the Slovak Carpathians intensive agriculture is practiced; in the rest of Carpathian countries small-scale agriculture prevails, e.g. in the Czech Republic 79% of farms are less than 5 ha (2004). Semi-subsistent, it combines crop farming (wheat, rye, barley, potatoes, vegetables and fodder crops) in forelands and cattle grazing on the mountain grasslands in the summer. Orchards and vineyards play a minor role in the Carpathian region (Figure 6-1).

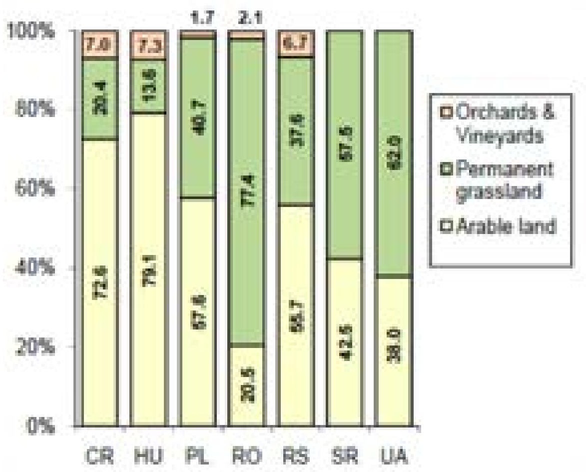


Figure 6-5 *Distribution of Carpathian-wide land use types (SARD-M, 2008).*

The traditionally managed agriculture in most parts of the Carpathians results in a wide variety of 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. These landscapes have strong cultural associations, provide a wide range of ecosystem services and associated economic benefits, and are rich in wildlife and biodiversity. Grasslands are generally 'plagioclimax' communities that have been traditionally maintained by some form of grazing and a cutting or burning regime.

Sheep breeding is a widely spread traditional agricultural activity in the Carpathian region. Farmers raising sheep still prefer the traditional methods developed centuries ago. Each spring, the sheep from every village are joined in large units and brought to the mountain pastures. These natural pastures are used up to the end of the autumn when the sheep are brought back to the villages for the winter period, and fed with hay mowed from the plateau´s grasslands. Most of the living traditions are based on the sheep life cycle and many people still engage in activities related to sheep-related products.

Small-scale agriculture is considered to have positive impact on the areas preservation of biodiversity, as long as it stays diverse and respects carrying capacity (Bignal and McCracken, 1996). A comparison of several land use–biodiversity loss gradients showed that ecosystem quality decreases as agricultural practices intensify: agro-forestry systems have an ecosystem quality of 50%, extensive agriculture of 25% and intensive agriculture as little as 10% (Reidsma *et al.*, 2006). For instance, in Sibiu County, Romania, semi-natural vegetation occurs on 60% of all farmed land, most of which is managed extensively. The long tradition of human presence in this mountainous area developed a farming system based on methods of mixed sheep and cattle grazing and mowing, mobile pastoralism on long and short distances. This area hosts rich flora of 5500 plant species (67% of Romania's total), and at least 11 hay meadow plant associations can be distinguished on high natural value grasslands (Beaufoy *et al.*, 2008).

Within the Carpathian Region, there are huge differences in the social and age structure, stability of the settlement and rates of unemployment. Looking at the distribution of employment opportunities, in Northern and Western Carpathians (Poland, the Czech Republic, the Slovak Republic, Hungary) the service sector plays a major economic role, while in Poland, Romania and the Republic of Serbia reliance on agriculture is still high (Ruffini *et al.*, 2008). Wide areas of the Carpathians are predominantly rural areas with only a few municipalities not classified as rural.

It has been reported that over the last two decades rural areas in Eastern Europe have faced economic decrease, reducing population numbers and land abandonment (Heidelbach, 2002). At present, the Carpathian Mountains of the Czech Republic are the most densely populated (205 p/km^2) followed by Poland (201 p/km^2). Least densely populated are Romanian and Serbian Carpathians. Population density highly correlates with the altitude – rather high in the forelands (over 150/km^2) and low (10-25/km^2) in the mountainous areas. Romania is found to face the highest probability for land abandonment and land use change in both surface area (8264.6 km2) and percentage (7.1%). Slovakia has the second highest surface area probability (2448.1 km2) and percentage (6.7%) for land abandonment or land use change. The biodiversity impact of land use change and abandonment is significant in both modelling outputs and historical data (Peters *et al.*, 2013). Withdrawal of grazing and abandonment of meadows in the Czech Carpathian grasslands has led to the overgrowth of dominant species, degradation of mountain grassland habitats, and diminished diversity of landscapes, habitats and species (Csagoly, 2007). It is only in Romania, the Slovak Republic and Ukraine that the area of permanent grassland is on the increase (> 50%).

6.2.2 Main impacts of climate change

Higher temperatures, rising CO_2 concentrations, changes in annual and seasonal precipitation patterns and frequency of extreme events will affect both productivity and quality of agricultural outputs in the region. For impacts on different types of grassland the reader is referred to Section 5.2.

2020-2050: Earlier occurrence of phenological development stages can be expected. In terms of effective global radiation and number of effective growing days the Czech Republic, Hungary, Poland, Romania, Slovakia and Ukraine show an increase in the mean production potential. A warmer climate may lead to an increase in the northern range over which crops such as soya and sunflowers may be grown and potential increases in yield from the longer growing season may be expected (Iglesias *et al.*, 2007). However in the Panonian plain further water deficits will limit rain fed agriculture. The CECILIA project has produced estimates of sensitivity of winter wheat phenology to climate change. Sowing date is determined mainly by soil moisture and due to increased drought (esp. in lowlands), favourable conditions will shift 3 days (ECHAM model) or almost 10 days (NCAR and HadCMAdditionally). Good news is that an increase of temperature by 1 °C during the grain filling phase reduces the length of this phase by 5%. Therefore total duration of growth may be reduced under SRES - A2 2050 (highest emissions scenario) by up to six weeks. Spatial analysis carried out for the winter wheat yield concerning altitude suggests that yield should increase especially in highlands, where increasing temperature will provide favourable conditions, rainfall will remain sufficient and soil conditions are still relatively good (Halenka, 2010). Good for winter wheat, the same conditions are projected to decrease maize yields in the lowlands. One of the threats is widening of the pests'

(Colorado potato beetle and the European corn borer) areas and an increase in their generation number by 2050.

In general, the more substantial water deficit during the critical part of the growing season (spring) in Central Europe may lead to a shift to winter crops, however harvesting conditions in June will not improve.

CLAVIER project produced predictions of future yields of wheat, maize, barley, potatoes and lucerne in North-West of Romania, underlining that the projections are valid only for this region (Figure 6-2).

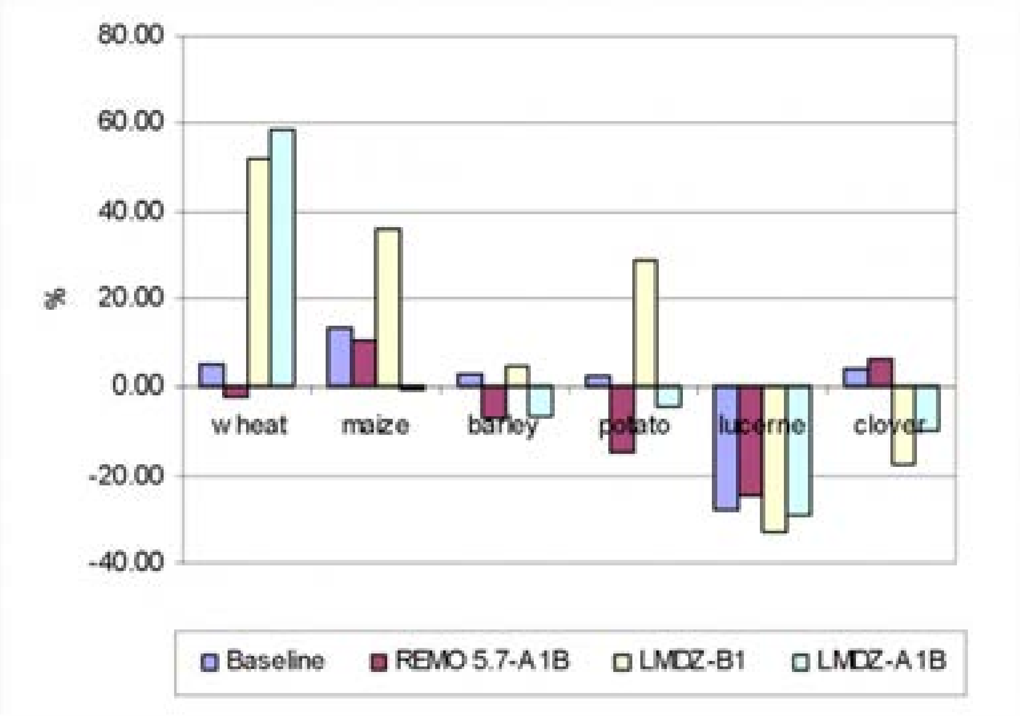


Figure 6-6 *Change in crop yields in the North-West region in 2020-2030 compared to the reference period 1975-2000 according to different climate scenarios (CLAVIER Project, 2007).*

2050-2080: In Poland, Czech Republic, Slovakia and Ukraine annual mean temperature is projected to increase 3 to 4°C. Annual rainfall is expected to increase as well, with more precipitation during winter and less in summer. Warmer climate may lead to potential yield increase due to longer growing season and increase in the northern range for soya and sunflower. In Hungary, Serbia and Romania a temperature increase of 3-5°C and decrease in annual rainfall are predicted, which may lead to reduced yields of maize and wheat. However, yields of crops with a greater requirement for heat may increase (CLAVIER Project, 2007).

6.2.3 Factors co-determining impacts and vulnerability

The traditionally managed agricultural landscapes of the Carpathians are under serious pressure. Land abandonment as well as forestry and agricultural intensification key pressures. Agriculture as a professional choice for young people has gradually lost attractiveness since the beginning of 90s. A shift is ongoing from employment in agriculture to the service sector (Csaki and Jambor, 2009). As a result, low-input, labour-intensive practices (traditional agriculture, cattle grazing on high altitude grasslands, cheese-making) may substantially decrease in the next decades, which will lead to overgrowth of grasslands and loss of part of Carpathians' cultural landscape. There is a need for change in the economic structure of the countryside and the creation of an attractive environment for living as well as favourable business environment, including the conditions for small entrepreneurs, i.e. to support a creation of new jobs by the diversification of economic activities, as well as to use general policy measures for improvement of the quality of life in the rural areas. The stability of the rural population and of civil infrastructure (like shops, schools, doctors, etc.) is a concern.

A working document of the European Commission outlines socio-economic factors that influence farmers' resilience (EC, 2009):

- Farm characteristics such as production type, size of the farm, level of intensity;
- Diversity of cropping and livestock systems, and the presence of other income sources apart from agriculture;
- Access to relevant information, skills and knowledge about climate trends and adaptive solutions; the role played by advisory services in facilitating adaptation;
- General socio-economic situation, farmers with limited resources or living in remote rural areas being most vulnerable.

Pastures in the Carpathians are particularly impacted by socio-economic dynamics. They presently disappear through changing land use and land abandonment: without management, grasslands are likely to succumb to colonisation by scrubs and forests. As a result they lose a substantial part of their biodiversity interest through the dominance of coarse herbs and grasses which outcompete the more fragile and rarer species; this will result in the loss of certain ecosystem services and a gain in others; for example, there may be fewer medicinal herbs, pollinating insects, socio-cultural associations, domestic animals including traditional breeds. As a side note: carbon sequestration may be increased where scrub and forest develop.

Mining industry has existed for decades in the Carpathians and is still, on one hand, a viable employment opportunity for local populations in Poland and Romania, and/or, on the other, a source of air pollution and degradation of fertile soil.

6.2.4 Policy (objectives) that can be affected by climate change impacts

- Romania is the only country in the region that established National Agency of Mountain Areas under the Ministry of Agriculture, Forestry and Rural Development;
- Slovakia: Agricultural Paying Agency;
- There is no policy specifically designed for the Carpathian Region in the Czech Republic; Concept of Agrarian Policy for 2004 – 2013 (CARP) (adopted by Governmental Decree No84/2004 on 9 June 2004);
- Concept of Agrarian Policy for 2004 – 2013 (CARP) (adopted by Governmental Decree No584/2004 on 9 June 2004);
- The Rural Development Programme (RDP) of the Czech Republic for the period from 2007 to 2013.

6.2.5 Potential adaptation measures and strategies

Many adaptations occur autonomously and without the need for conscious response by farmers and agricultural planners (Brooks *et al.*, 2005). On the farm scale potential adaptation options can include changes in sowing dates and crop varieties, improved watermanagement and irrigation systems, adapted plant nutrition, protection and tillage practices.

To achieve broader goal of sustainable agriculture and rural development in the changing climate, alterations on a policy level that can create synergy with autonomous adaptation should be considered (Urwin and Jordan, 2008). Taking into account developments in the Carpathian region (land abandonment, overgrazing, aging, limited budgets for governmental action) the following management measures are suggested:

Measure 1: Agro-environmental programmes
Agro-environmental programmes aim to harmonize relations between the production of food and the conservation of the environment while improving quality of life of village communities. Influencing duration and system of grazing, sustainable mowing and grazing, reduction of chemical fertiliser and pesticides' use are just some of the options that make farmer applicable for financial support. For instance, farmers in the Czech Republic can get paid between 76 and 176 €/ha/year in case of

adapted grazing, enhancing biodiversity on agricultural grasslands (Kaphengst et al; 2011). In other EU Carpathian countries, this management measure is included in the general agro-environmental subsidies (See also 5.2.5).

Measure 2: Additional facilitating measures
The following measures complement agro-environmental programmes and will facilitate transition to sustainable agriculture, tackling major causes of ecosystem and economic degradation - land abandonment, overgrazing and climate change impacts:

The improvement of the professional skills / Providing technical assistance
Assisting in the development of professional skills in order to contribute to the improvement of the knowledge and professional competence of the farmers and other people involved in agriculture. To ensure that rural farmers are benefitting from the above stated governmental systems and subsidies, technical assistance and supervision is provided. E.g. Adept Foundation is developing training courses and public awareness programmes in the Tarnava Mare region (Romania).

Improving processing and marketing
Higher efficiency of the processing and marketing of agricultural and fish products will eventually contribute to the implementation of the community acquis (the body of common rights and obligations which bind all the Member States together within the European Union), increase the competitiveness and at the same time promote more environmentally friendly production methods. A brand promoting local food was created in the Romanian Tarnava Mare region. The brand and a proper website, www.discovertarnavamare.org, help communicating the added value of sustainably produced food and other local products including responsible rural tourism.

Connecting local communities, non-governmental organizations, environmental activists and researchers
Professional support and increased contact with private conservationists, national and local non-governmental organizations (NGOs) is highly important and could help raise awareness in addition to providing sound management expertise. Role of volunteers and activists should not be underestimated as they can aid with reporting, data collection, help elaborate and implement ideas. Habitat dynamics are very complex, therefore long-term involvement of researchers would be beneficial for monitoring changes in the species composition.

There is a need for change in the economic structure of the countryside and the creation of an attractive environment for living as well as a favourable business environment, including the conditions for small entrepreneurs, i.e. to support the creation of new jobs by the diversification of economic activities, as well as to use general policy measures for improvement of the quality of life in the rural areas where the social sector (like shops, schools, doctors, etc.) and civil infrastructure are in poorer condition.

6.2.6 Integrated vulnerability assessment of agriculture

Due to changing precipitation, temperature, and seasonality, agriculture will experience substantial pressures. Agriculture may become feasible at higher altitudes. In some parts of the Carpathians maize and wheat yields will decline, whilst elsewhere sunflower and soya yields might increase due to higher temperatures and migration of these crops' northern limit. 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 also 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 particularly vulnerable through the combined impacts of climate change and socio-economic dynamics as the pastoralists on whom grasslands depend for both their existence and the implementation of potential adaptation measure are abandoning grazing and land management activities. Thus the traditional mixed agro-systems in the Carpathians disappear through a combination of land abandonment, land use change and increased advancement of forest area, encouraged by changing climate conditions.

6.3 Tourism

6.3.1 Current status

Tourism plays an important role in the economies of the Carpathian countries. It generates ca. 7-12% of the Carpathian Region's GDP. The tourism sector is expanding dynamically and it seems to be one of the most thriving branches of economy (Borsa *et al.*, 2009). The most important tourism sectors are active tourism, all-year ecotourism and recreational tourism. The boundaries of the different eco-, cultural and active tourisms are rather vague. Their common characteristic is that they are all-year and touristic turnover in most resorts does not show strong seasonality, except for active winter tourism. Active all-year round ecotourism (visiting National Parks, fishing, hunting, trekking, hiking), cultural tourism (visiting historical sites, cities, monasteries, festivals) and health tourism together make up for up to 70% of overnight stays. 60% of the overnights occur in the summer period, and 40% in the winter period.

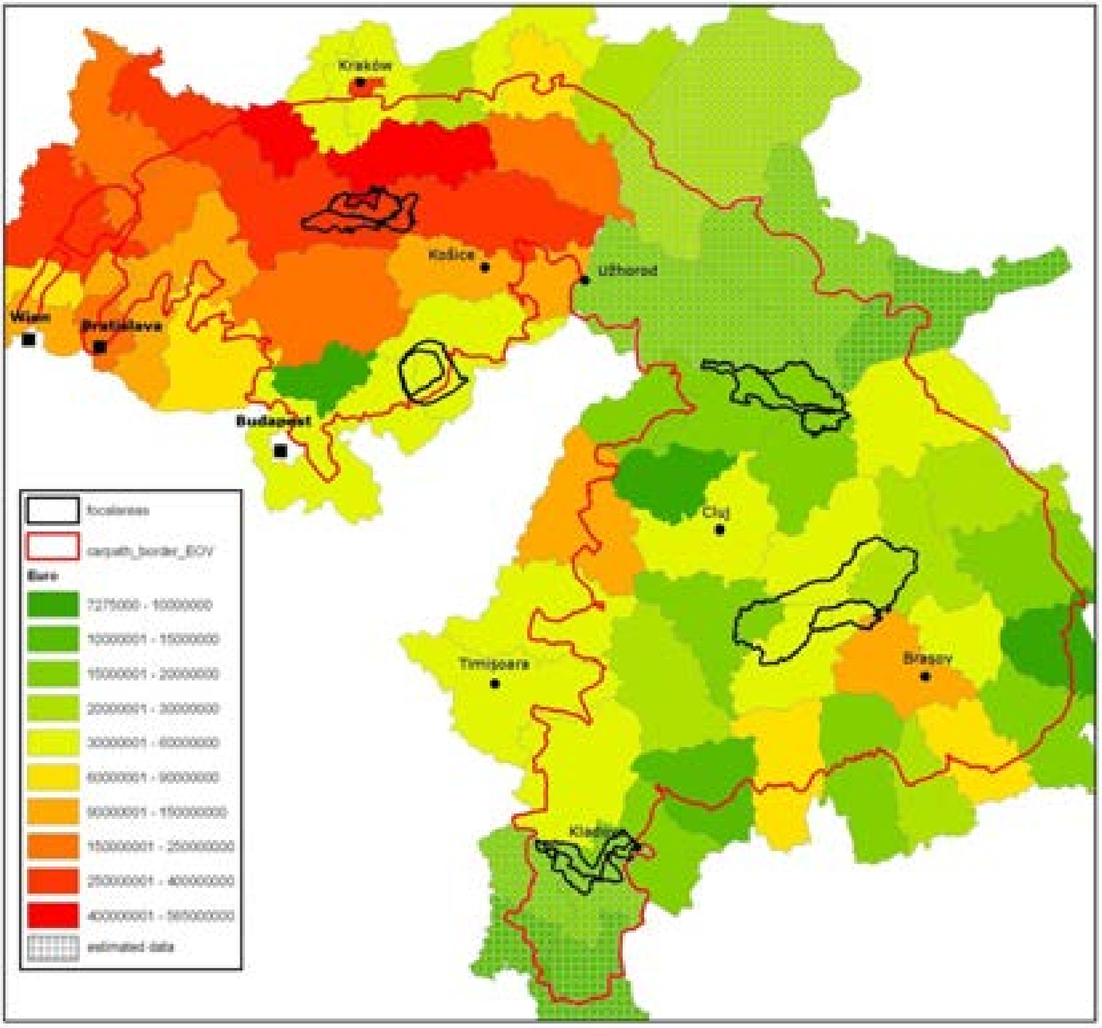


Figure 6-7 *Estimated income from tourism (in NUTS3 level, 2011) (Peters et al., 2013).*

The construction of new ski resorts has become a characteristic tendency throughout southeast Europe. Analysis of spatial and temporal snow cover changes in the Little Carpathians (South-western Slovakia) based on data from 20 stations for the 1950-2004 time period showed, in spite of substantial increase in temperature means and some precipitation decrease, no remarkable decrease in snow cover after 1990 (Lapin and Faško, 2005). Time analyses of snow cover variability and trends within 1921-2006 time period in the High and Low Tatras regions revealed unequal trends (Lapin *et al.*, 2007). Main drivers of observed changes are increasing average temperature, increasing or decreasing precipitation and to a certain extent also changes in atmosphere circulation patterns. The long-term snow cover time series analysis showed a significant decrease of snow cover characteristics in many parts of Slovakia, with an exception of mountainous regions, where the snow cover is increasing, primarily as a result of increasing precipitation during winter season (Lapin *et al.*, 2007).

6.3.2 Main impacts of climate change

Changing climatic conditions will have both positive and negative impacts on the tourism sector in the Carpathian region in the medium- and long-term (CEU, 2008). The CarpathCC project has elaborated snow change animation maps showing that the change will be significant (Peters *et al.*, 2013). Decrease in snow cover duration in Slovakia and Romania with increasing temperature and increasing precipitation is anticipated (Lapin and Faško, 2005; Micu, 2009). In case of mountain regions, the largest snow cover decrease (meaning number of days with snow) will be at the beginning (September) and in the end (April) of the winter season. In other words the winter season will become shorter. In general, low-lying skiing regions will be more affected by climate change than skiing regions at higher latitudes. In fact, Kostka and Holko (2004) conclude that by 2030 alpine skiing regions within the 1150-1500 m a.s.l. might by uneconomic and by 2075 also regions in 1500-1850 m a.s.l.. Higher variability in snow cover (duration) can also be expected with extremely high and low snow cover (such as winter seasons 2005/2006 and 2006/2007). The South-Carpathians' tourism will face the greatest magnitude of the change (e. g. Djerdap, Mt. Mehedinti, Mt. Orsova, Mt. Almas, Mt. Lokven, Mt. Semenic, Mt. Anina, Mt. Vulcan, Mt. Retezat, Mt. Rusca). The change will be the lowest in the North and Northeast-Carpathians' tourism (e. g. the Tatras and their neighbourhood) (Peters *et al.*, 2013).

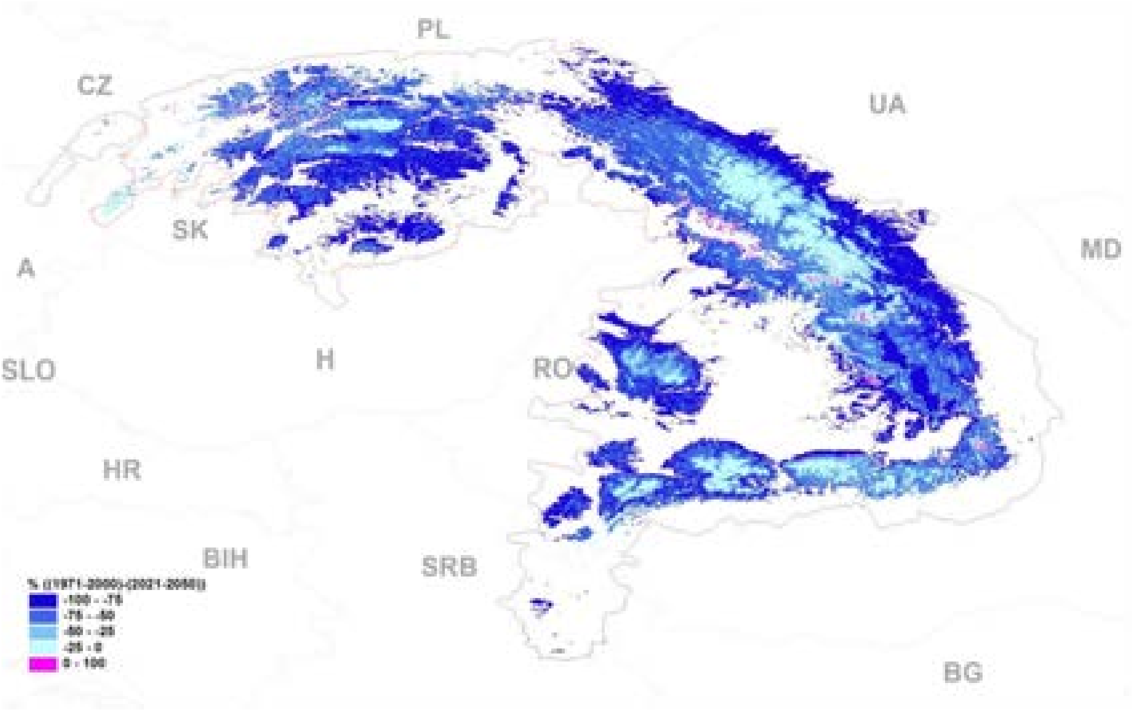


Figure 6-8 *Difference in the number of years with at least 80 days of snow cover of at least 20 cm snow depth (1971-2050) (Peters et al., 2013).*

However, as tourism in the Carpathians is presently very diversified, only a small part of the visitors depends on the snow availability. Thus snow cover and snow depth changes will not have such a large impact on the entire tourism turnover as was formerly supposed. Besides, the profile of the old, winter sport-based resorts is changing, meaning that tourism in higher mountains is already adapting to new conditions. At the same time, the summer tourist season will be longer and distribution of tourist visits will be more even. Countries in the Carpathian region might also benefit from shifting tourist flows from countries for example in the Mediterranean, where the tourist industry has been identified as vulnerable to climate change, as a result of reductions in thermal comfort of beach tourism (Jol *et al.*, 2008). The CarpathCC project suggests that ecotourism, summer tourism, health tourism, vocational tourism could be positively influenced by climate change, and mainly the possibilities of winter sport will become more limited. Based on background information and analysis of statistics, CarpathCC assess the following changes in number of tourists due to climate change until 2050: active all year tourism (+0.8%), ecotourism (+0.8%), health tourism (+0.6%), vocational tourism (+0.1%), and active winter tourism (-0.5% decreasing). Thus it is estimated that climate change could bring 60-75,000 additional tourists per year with 9.6-12 million EUR additional revenue for the region. However, extreme weather events in the region and shocks in the adjacent Central-European and Mediterranean regions may decrease this volume (Peters *et al.*, 2013).

Other regional studies support that climate change does not bring only negative effects, but depending on the adaptive capacity of resorts, it can also bring positive effects (e.g. Surugiu *et al.*, 2011). These have to be included in vulnerability studies.

Summarising potential impacts of climate change are:
WINTER season:

- Long-term snow cover time series (data from 20 stations in Slovakia) analysis showed a significant decrease of snow cover characteristics in many parts of Slovakia, with an exception of mountainous regions, where the snow cover is increasing, primarily as a result of increasing precipitation during winter season (Lapin *et al.*, 2007). In general, low-lying skiing regions will be more affected by climate change than skiing regions at higher latitudes;
- On the other hand (IPCC, 2007) it is anticipated that globally natural snow cover decreases especially at the beginning (September) and in the end (April) of the ski season in Central Europe. So, winter season will become shorter;
- These tendencies seem to contradict with the development of new locations for ski tourism being strongly supported by some governments (e.g. in Romania and Bulgaria).
- *SUMMER season:*
- Summer tourist season will be longer;
- In lower lying areas of Central Europe, in the Danube basin, tourism will be affected by the increasing frequency and magnitude of events such as flooding heat waves, fires, deteriorating quality of natural lakes e.g. Hungary (lake Balaton). On the other hand, summer tourism will be longer and distribution of tourist visits will be more even;
- Countries in the Carpathian region might also benefit from shifting tourist flows from countries for example in the Mediterranean, where tourist industry is very vulnerable to climate change (CEU, 2008).

6.3.3 Factors co-determining impacts and vulnerability

Climate change is only one aspect of global change and other aspects of the human / economic systems strongly influence the profitability of the tourism sector. Disposable income of travellers, preservation (or not) of the beautiful landscapes, political stability in the region and attractiveness of other destinations in the same price range are just some of the factors that will define future of the tourism in the Carpathians.

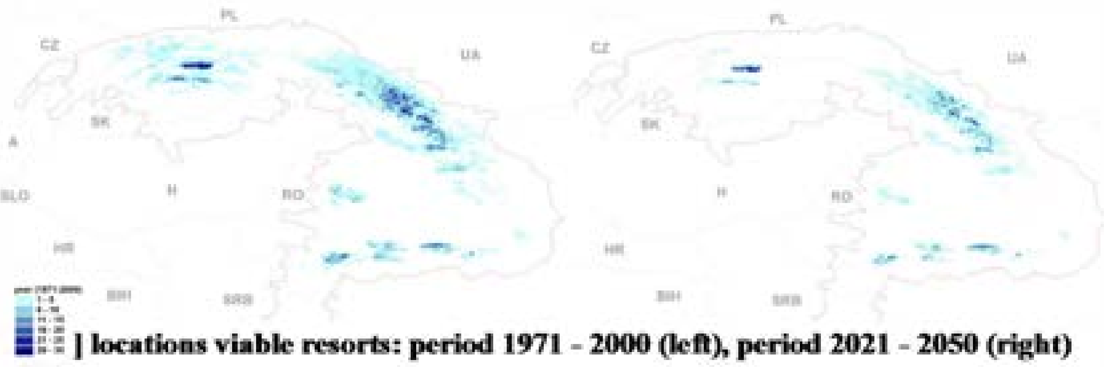
Since a clear-cut connection between weather variables and tourism indicators is missing, some local studies have asked tourism managers about vulnerabilities. They point at additional factors like altitude and exposure of ski tracks, presence of artificial snow installations and the conditions and quality of accommodation facilities (Micu and Dincă, 2008). The results of a questionnaire carried out in the CarpathCC project (Peters *et al.*, 2013) show that landscape degradation can seriously impact attractiveness of the Carpathian region in the near future, and it could impair positive climate effects. Pests and invasive species in a warmer climate have the potential to harm the forests on a very large scale (e.g. in the Tatras), logging is thriving, old mines operate and new mines are opened using dangerous technologies. Also, impacts of climate change on agriculture, forestry, fishery, and infrastructure could impact the tourism sector, decreasing the quality of the services provided. Finally, altitudes and the level of diversification affect vulnerability of tourism services (e.g. Surugiu *et al.*, 2011).

Tourism characteristics are heterogeneous. For example, although the western part of the Carpathians has more diversified infrastructure it also has higher accommodation capacity and effectively a slightly lower utilisation rate than in the east. Such factors result in regional disparities in adaptive capacity and vulnerability.

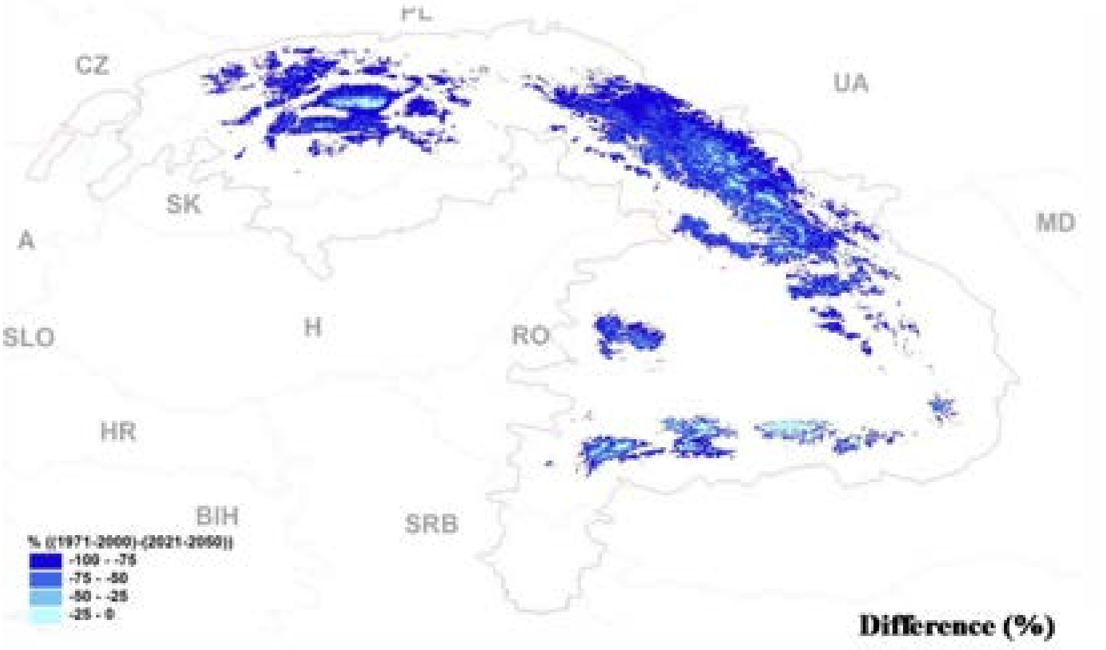
6.3.4 Policy (objectives) that can be affected by climate change impacts

National strategies for tourism development can be compromised by climate change. Taking into account impacts of climate change in tourism strategies and in planning for new investments in the tourism sector can help reduce potential financial losses. Some of the countries in the region have already started to take these concerns into account when developing their national strategies for adaptation to climate change. For example, in the Romanian national climate change strategy impacts of and adaptation to climate change with regards to tourism are analysed. In the case of Hungary, tourism is mentioned in the national climate change strategy, although no extensive discussion is provided on the sector in the document. Strategic documents on climate change in Bulgaria also contain discussion of tourism.

The CarpathCC project offers an analysis of the economic viability of ski resorts under climate change (Peters *et al.*, 2013`, page 448-453). Based on literature review a resort can be economically viable when having 120 days of snow-covered ski area, and in seven out of ten winters there is snow cover of at least 30 cm on at least 100 days between 1 December and 15 April. Following those criteria, Figure 6-5 shows the number of winters between 1971-2000 and 2021-2050, in which during at least 100 calendar days/year, between 1 December and 15 April, snow cover is at least 30 cm.



| locations viable resorts: period 1971 - 2000 (left), period 2021 - 2050 (right)



Difference (%)

Figure 6-9 *Number of years in which criteria for an economically viable ski resorts are met.*

6.3.5 Potential adaptation measures and strategies

Tourism strategies may discuss climate change impacts and adaptation measures related to the sector and in relation to the substantial amounts of money that are being invested in tourism facilities and infrastructure. In Hungary, Romania and Bulgaria, national climate change strategies and action plans have already been developed (or are currently being developed), and impacts on the tourism sector are taken into consideration. No national strategies and action plans on climate change and adaptation to climate change exist yet in Slovakia, Serbia and Ukraine.

There may be trade-offs between environmental protection and development of tourism that have to be taken into account when planning adaptation. An example is generating artificial snow. Options for adaptation to climate change in the tourism sector include promoting new forms of tourism, for example ecotourism, cultural tourism (IPCC, 2007), or conference tourism. Few comprehensive assessments of the impact of climate change on tourism and of adaptation exist (CEU, 2008). Recent studies mostly focus on impacts and adaptation in a particular region or resort (e.g. Surugiu *et al.*, 2011).

Beyond trends in rainfall, snow and temperature there are the impacts of heavy weather situations (e. g. storms, snowstorms, extreme heat waves and rapid falls in temperature). Adaptation options here are infrastructural (e.g. road design), institutional (e.g. through building codes) and informational (e.g. informing tourists of extreme weather risks).

6.3.6 Integral vulnerability assessment of tourism

Changing climatic conditions will have both positive and negative impacts on the tourism sector in the Carpathian region. Ecotourism, summer tourism, health tourism, vocational tourism can be positively influenced by climate change, and mainly the possibilities of winter sport will become more limited. Projections of snow duration and depth indicate substantial change for the coming 50 years. However, as tourism in the Carpathians is presently very diversified, only a small part of the visitors depends on the snow availability. Thus snow cover and snow depth changes will not have such a large impact on the entire tourism turnover as was formerly supposed. Besides, the profile of the old, winter sport-based resorts is changing and the majority of the tourists visit the hotels and pensions in the summer periods nowadays, meaning that tourism in higher mountains is already adapting to new conditions. It is estimated that climate change can bring 60-75,000 additional tourists per year with 9.6-12 million EUR additional revenue for the region. A Southeast-Northwest gradient of vulnerability is reported, with the South-Carpathians' tourism the most vulnerable (see Figure 6-6). Consultations with stakeholders support this finding (Peters *et al.*, 2013).

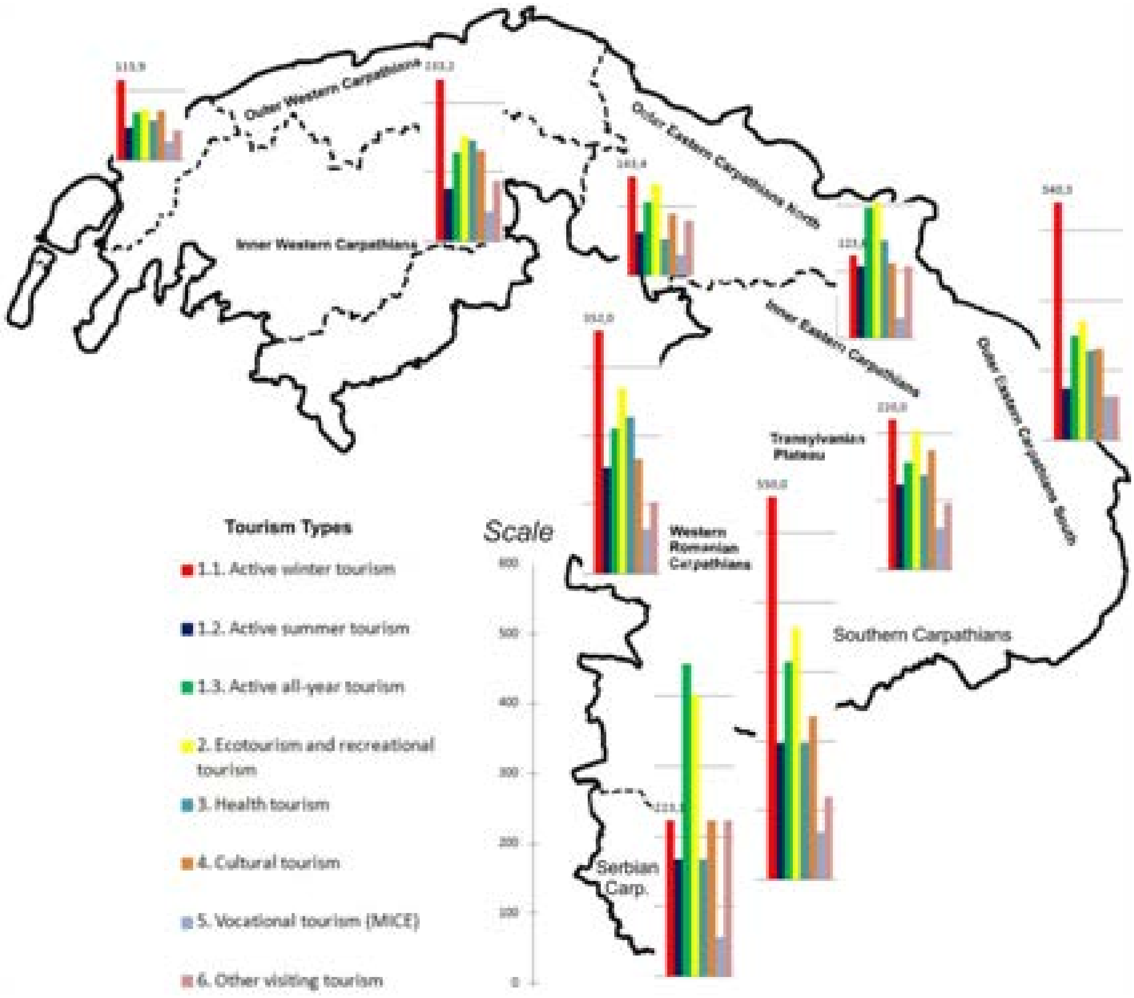


Figure 6-10 *Vulnerability of tourism in the Carpathian macro-regions (Peters et al., 2013).*

7 Costs and benefits of adaptation

This chapter provides an overview of adaptation measures relevant for the Carpathians. Furthermore it summarizes the main findings on available information on adaptation measures and economic studies that evaluated measures to adapt for climate change in the Carpathians and measures that have been implemented elsewhere but could be applied to the Carpathians.

The chapter summarises the information provided in the CARPIVIA interim report and the outcomes of the CarpathCC project, in particular Service Request 4 Task 3 and Task 5 (Arany *et al.*, 2013b; Arany *et al.*, 2013a).

7.1 Current status adaptation

Adaptation planning in the Carpathians is limited. Romania, Bulgaria and Hungary have the most developed climate change policies. Slovakia recently approved its adaptation strategy (Jan 2014, www.minzp.sk/files/oblasti/politika-zmeny-klimy/nas-sr-2014.pdf). Non-EU member state Serbia is ready to develop a climate change strategy. The other Carpathian countries do not have climate change strategies and adaptation policies. Table 7-1 gives an overview of the type of measures in these strategies. The ICPDR Support Study 'Danube Study - Climate Change Adaptation (Study to provide a common and basin-wide understanding towards the development of a Climate Change adaptation strategy in the Danube River Basin)' compiled an overview of the adaptation measures proposed in the different national adaptation plans.

Table 7-1
Status of development of national climate change strategies and action plans related to adaptation to climate change in the region.

	Slovakia	Hungary	Serbia	Bulgaria	Romania	Ukraine
National Climate Change Strategy	yes	yes (2008-2025)	no, but intention to develop	yes (action plan 2005-2008)	yes (2005-2007)	no
Adaptation section included	-	yes	-	yes (only agriculture and forestry)	yes	-
Action plan for implementation	-	currently being developed	-	-	yes	-
Separate strategic document on adaptation	yes (Jan 2014)	yes	no	no	yes, currently undergoing public consultation	no

7.2 Prioritised adaptation measures

The vulnerability to climate change of the ecosystem types water resources, forests, (semi-)natural grasslands and wetlands, and of the ecosystem-based production systems forestry, agriculture and tourism has been assessed by both the CARPIVIA and CarpathCC project. These assessments made it possible to define the adaptation requirements in the Carpathian region and to identify adaptation measures. Long lists of adaptation measures have been presented in the previous chapter for the different ecosystems and ecosystem-based production systems. The long lists have been further appraised and discuss with stakeholders in order to yield a set of prioritised measures. Selection criteria included:

- To be effective in reducing climate change impacts on ecosystems and ecosystem-based production systems in the Carpathian region (see BOX 7-1);
- To have positive side effect on other economic and social sectors or other ecosystems / environmental objectives;
- To be applicable in the Carpathian region and acceptable for stakeholders.

This section presents the prioritised measures. For each these measures a factsheet has been prepared under the CarpathCC project (SR4 Task 5, Annex 6 (Arany *et al.*, 2013a)). These factsheets provide a short description of each measure, as far as information is available. The factsheets aimed to be compatible with the CLIMATE ADAPT EU format.

BOX 7-1: Typical climate change impacts on ecosystems to be addressed in adaptation

- Water resource ecosystems are impacted by floods and droughts;
- Forest ecosystems are impacted by decreased water availability together with rising temperatures, storms, erosion of topsoils, and pests, resulting in loss of forest ecosystem services;
- Wetland ecosystems are impacted by lower precipitation in combination with human activities;
- (Semi-)natural grassland ecosystems are impacted by habitat loss and fragmentation due to changes in temperature and water surplus or decrease or localized flooding and erosion remove top soil. The impact of climate change depends strongly on the stress caused by other human factors;
- Agricultural grassland ecosystems are impacted by water deficits and extension of pests.

Prioritised adaptation measures forests and forestry

The most suitable adaptation measures for forestry in the Carpathian region are structured under six “umbrella measures” (Source: CarpathCC SR4 Task5 (Arany *et al.*, 2013a)).

1. Develop and support ecosystem monitoring systems
   - Supporting and harmonizing monitoring across countries and organisations;
   - National and European monitoring of newly emerging pests and pathogens and for monitoring of changes in distribution, population dynamics and virulence of present pest and pathogen species;
   - Awareness and capacity building: Improving the use of forest monitoring data for the assessment of forest vulnerability to climate change; Based on forest monitoring data, assessment of forest vulnerability to climate change and dissemination of this information to all stakeholders;
   - Improving the systems of forest monitoring in forests under high conservation regime, mainly with focus on the adverse effects of climate, with special emphasize on monitoring of pests and pathogens;
   - Hazard mapping.
2. Implementing adaptation measures at landscape scale
   - Preservation of large-scale, not fragmented green areas;
   - Preserving and restoring large-scale corridors;
   - Support cross-sectoral cooperation to allow for the development of landscapes adapted to climate change.
3. Enable natural adaptation in forests under high level of conservation
   - Non-intervention management, network of areas with non-intervention management;
   - Development of strategies for disseminating information on processes in protected forests under no-management regime;
   - Establishing transition zones between strictly protected and managed forests – re-evaluating the present zones of nature conservation.
4. Apply ecosystem-based adaptation measures in managed forests
   - Stabilizing and improving the protection of forests;
   - Securing and strengthening important forest functions;
   - Promoting concepts such as close-to-nature-forestry and continuous-cover forestry, i.e. broader use for selection and shelterwood systems; reduced clear-cutting, support natural regeneration; applying the concept of continuous-cover forestry i.e. supporting shelterwood and group selection systems of forest regeneration, and avoiding clear-cutting, mainly in stands the vulnerability of which may increase after opening of the canopy;
   - Financial support programme to promote and encourage the introduction of locally adapted tree species in the lowlands;

- Promoting change in species composition towards higher shares of drought tolerant species, including use of provenances better adapted to drier and warmer climates;
- Increasing the share of drought tolerant species in regions where drought is expected to be more pronounced in the future; Reducing the share of water demanding species, mainly of Norway spruce growing outside the range of its natural distribution;
- Supporting natural selection through broader use of natural regeneration; supporting the genetic diversity of present forests, and consider using provenance better performing in drier and warmer climates;
- Preserving valuable gene pools: Preventing undesirable loss of valuable gene pools by their relocation; establishing synthetic sources of forest reproductive material ex situ for the most vulnerable species.

5. Integrate wetland protection with flood control practices
   - Integration of wetland protection with flood control practices; Support programmes aiming for wetland and peatland restoration, floodplain rehabilitation and creation of new wetland and lakes to enhance local water retention capacity and support biodiversity;
   - Maintenance of alluvial forests.
6. Increase awareness on the importance of integrated watershed management in adaptation to climate change, and the effects of forests, wetlands and grasslands on watersheds typology
   - Forest management within the water protection and sanctuary zone for the purpose of drinking water protection;
   - Funding for water retention in drought-endangered forest landscapes (for both protected and managed forests);
   - Increasing awareness on the importance of integrated watershed management in adaptation to climate change, and the effects on forest on watersheds hydrology;
   - Increase cooperation between protected area managers and other stakeholders, especially water managers.

Prioritised adaptation measures wetlands

The following measures are considered to be the most suitable adaptation measures for wetlands (Source: CarpathCC SR4 Task5 (Arany *et al.*, 2013a)):

1. Develop and support ecosystem monitoring systems
   - Hazard mapping;
   - Preparing a network to monitor the state of waters and aquatic ecosystems in the region.
2. Implementing adaptation measures at landscape scale
   - Preserving and restoring large-scale corridors;
   - Support cross-sectoral cooperation to allow for the development of landscapes adapted to climate change.
3. Implement agri-environment measures.
4. Integrate wetland protection with flood control practices
   - Integration of wetland protection with flood control practices; Support programmes aiming for wetland and peatland restoration, floodplain rehabilitation and creation of new wetland and lakes to enhance local water retention capacity and support biodiversity;
   - River and floodplain restoration.
5. Wetland restoration.

Prioritised adaptation measures grassland

The following measures are considered to be the most suitable adaptation measures for Grasslands (Source: CarpathCC SR4 Task5 (Arany *et al.*, 2013a)):

1. Develop and support ecosystem monitoring systems
   - Hazard mapping.
2. Implementing adaptation measures at landscape scale
   - Preservation of large-scale, not fragmented green areas;
   - Preserving and restoring large-scale corridors;
   - Support cross-sectoral cooperation to allow for the development of landscapes adapted to climate change.
3. Restore degraded grasslands with high biodiversity value and preserve existing small grasslands and pastures
   - Restoration of degraded grasslands with high biodiversity value;

- Biomass removal to avoid nutrient accumulation (as part of traditional management);
- Preparation of Natura2000 management plans;
- Extensive use of grasslands.

4. Implement agri-environment measures.
5. Diversify species and breeds of crops and animals with locally adapted breeds
   - Diversify agricultural landscapes;
   - Being innovative and linking opportunities e.g. sustainable food production.
6. Integrate wetland protection with flood control practices
   - River and floodplain restoration.

7.3 Actor groups involved

Actors involved in adaptation measures can be grouped as 1) actors involved in decision making, 2) actors involved in the implementation and operation of measures, and 3) actors affected by the measures.

Actors involved in decision making
Depending on the scale of measures the national, regional or local government is involved in decision-making in cooperation with the actors involved in implementation and operation of measures.

Actors involved in implementation and operation of measures.
The actors involved in implementation and operation of measures depend on the ecosystem to which the measures relate. A frequent actor in measures benefiting water bodies for instance is the organisation responsible for water management in a region or country. For the other ecosystems (grassland, forestry, wetlands, agricultural area) their respective management organisations or the sector itself are responsible for the implementation of measures. Awareness raising and communication measures can effectively be initiated by NGOs.

Actors affected by measures
It depends on the measure which actors will be affected. Actors like the agricultural, industrial, energy, forestry and tourism sector and, households could be affected (positively or negatively) by the measures.

7.4 Costs and benefits of measures

Each of the selected measures reported in 7.2 directly addresses the foremost climate change threat identified for the ecosystems at hand. The inventory from literature, web sources and by means of consultation resulted in an overall overview of climate change adaptation measures applied inside and outside the Carpathian region for forests, grasslands and wetlands (and water resources). However, information about the effectiveness of measures for the Carpathian region was very limited. The success of a specific measure has often not been evaluated, as the literature is mainly describing the implementation of the measure of itself.

This lack of information makes it largely impossible to indicate costs and benefits of the identified measures. The CARPIVIA interim report already concluded this, the analyses part of SR4 of CarpathCC confirm this conclusion. A reason why data is not available according to CarpathCC is: “The newness of adaptation and the long-term nature of climate change means that it is too early to determine what ‘best practice’ is and there is a general shortage of case studies for showing practitioners what adaptation-in-action actually looks like. Practitioners are still discovering how best to approach adaptation.”

In this section we present a general overview of costs and benefits of adaptation strategies. We have selected costs and benefits relevant to climate impacts and measures in the Carpathian region. For comparison we included results from international studies. Section 7.5 offers a limited number of specific case examples of adaptation measures, along with their cost and benefits for the specific setting of the Carpathian region. Adaptation measures have been selected for each of the studied ecosystems and ecosystem-based production systems.

7.4.1 Assessing costs and benefits of adaptation measures

In their review of studies on assessing costs of adaptation to climate change – especially the UNFCCC study on climate change (Parry *et al.*, 2007) are critical about the quality and coverage of studies they analysed. Sectors like ecosystems, energy, manufacturing, retailing and tourism hardly have been included in assessments of costs of adaptation, while sectors that have been included are often only partially covered.

Another gap concerns the focus on public adaptation over private adaptation. This is primarily because public adaptations are easier to identify than are the autonomous adaptations individuals and firms are likely to undertake. According to Parry *et al* (2009), adaptation to climate change is essentially private, in contrast to mitigation. Parry *et al* (2009) note that private *autonomous* measures will dominate the adaptation response as people autonomously adjust their buildings, change space-cooling and -heating preferences, reduce water use, alter holiday destinations or even relocate.

A challenge in assessing costs of adaptation is that adaptation is locally specific. This means that the applicability of general data is limited, especially for non-market effects of climate change. In so far estimates of costs of (no)adaptation concern non/market values (non-use values like bequest, option and existence values) of for instance fresh water ecosystems exist, reusing estimates made for other sites is expected to result in unacceptable biases (Kristofersson and Navrud, 2005; Brander and Florax, 2006).

Another issue, which Parry *et al* (2009) point at, is that much damage will not be adapted nor mitigated over the longer term, and thus a so-called residual damage will remain. Parry *et al* (2009) conclude that investment needs are probably under-estimated in the studies they have reviewed, and that the studies have a number of deficiencies, which need to be addressed in the future. If for all relevant sectors in a region, valid assessments for cost of adaptation measures would be available indeed, then the total costs of adaptation should be calculated as follows[4]:
Cost of adaptation = cost adaptation measures + residual impacts of climate change + transaction costs of implementing adaptation measures[5]

The information on adaptation that we reviewed has various weak points. Firstly, mainly information on investment costs of adaptation measures are reported. Studies that explicitly report on operating costs of the measures are rarely available. Furthermore, the available cost information lacks details on unit costs or the possibility to calculate unit costs. Unit costs are preferable to total costs since unit costs could be reused for other sites. Neither cost estimates for the residual impacts of climate change, nor transaction costs of implementing adaptation measures have been found.

Another main gap that we observed from reviewing economic studies on climate threats concerns benefit estimates of adapting measures, especially benefits for non-market effects like biodiversity and water quality. Much of our study region has not been covered by economic evaluation studies for the various climate change threats that the region faces. The CarpathCC SR 4 Task 5 report suggests to look at the effectiveness of measures, to be understood as "a judgment about whether or not the expected objectives and targets of the measure have been achieved..." (Environmental Terminology and Discovery Service/ETDS), i.e. whether - or how far - the measure at hand achieves its purpose (Arany *et al.*, 2013a).

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[4] Note that cost of adaption is only part of the overall cost of responding to climate change, as it also includes costs of mitigation (reducing the extent of climate change).

[5] All in terms of discounted values.

Yet, estimating (future) effectiveness is not a straightforward task either. It has several inherent uncertainties, because it "depends on the sequence and interaction of adaptations over time" (Adger *et al.*, 2005). The main issues determining these uncertainties are:

- General uncertainties regarding the impact of measures - there may be uncertainty over how a particular adaptation option will work even under defined conditions;
- Effectiveness of an adaptation option introduced by an organization may be reliant on actions taken by others;
- Effectiveness of an adaptation action may depend on the future— unknown— state of the world;
- Side effects: an adaptation measure may be effective at reducing the impacts of climate change or increasing opportunities in one location or time period, it may increase pressures ‘downstream’, or lessen the abilities of others to adapt to climate change.

Due to these uncertainties, the evaluation of a measures´ effectiveness is a difficult task. Hence, in the assessment in CarpathCC, ‘effectiveness’ was scored as to what extent a measure addresses the foremost climate change impacts identified for the specific ecosystem. This qualitative assessment of effectiveness was used as a selection criteria for the measures listed in Section 7.2.

The next sections summarize the main findings on our review of economic studies that evaluated measures to adapt for climate change in the Carpathians and measures that have been implemented elsewhere but could be applied to the Carpathians. First, we present a general overview of costs and benefits of adaptation strategies. Since few reviews are available for the Carpathian region, we also present information from international sources. Next, Section 7.5 offers a limited number of specific case examples of adaptation measures for which cost and benefits have been identified.

7.4.2 Reported climate change costs

This section offers typical costs associated with climate change impacts. The type of costs resulting from climate change mentioned in the reviewed studies concern:

- Damage by climate change caused flooding in:
    - Bulgaria: € 460 mln. in 2005
    - Hungary: € 519 mln. in 2006
    - Romania: € 1,539 mln. in 2005 and € 471 mln. in 2008;
- Reduced farm’s mean annual energy yield due to changes in the wind in north west of Hungary: 5.5% and 10% per year between 2031 and 2041;
- A temperature rise will diminishing the cooling efficiency of the Kozloduy Nuclear Power Plant power plant in north west Bulgaria, thereby reducing the annual energy production during 2021-2050 with 1%;
- Less tourist accommodation expenditures due to temperature rise in Romania’s sky resorts (November-April), taking into account the effect of the temperature increase, snow depth variation and extreme weather events occurring in mountain resorts on tourist flows (Surugiu *et al.*, 2011):
    - Predeal: a 1ºC *in*crease in temperature leads to losses of €113,700 (estimating a very modest reduction in overnight stays of under 0,5%) (Surugiu *et al.*, 2010)
    - Sinaia: a 1ºC *in*crease in temperature leads to losses of €23,500;
- Less tourist accommodation expenditures due to temperature rise in Hungary:
    - Lake Balaton: 1% until 2% *in*crease in tourist accommodation expenditures
    - Veszprém: 2% *de*crease in tourist accommodation expenditures.

7.4.3 Climate change benefits

This section offers typical benefits associated with climate change impacts. We have selected benefits that are likely to occur in the Carpathian region, yet have not restricted ourselves to studies from the region. Benefits resulting from climate change that have been quantified in the reviewed studies, concern:

- More tourist accommodation expenditures due to temperature rise in Romania’s Black Sea Coast: An *in*crease in temperature in July-August from 22ºC to 23ºC translates into a gain of +4,095 overnights and +163,800 Euro in economic terms for the seaside resorts;

- Increased gross agricultural output due to various climate change factors in the north east of Bulgaria: + 11.5% until + 23.16% ;
- Extra income for water based recreation due to an increasing number of visitors, as a consequence of climatic warming in Canada;
- Extra agriculture productivity for specific time horizons and specific scenarios for temperature rise in Central Europe South.

7.4.4 Costs and benefits of ecosystem-based adaptation measures

This section reviews costs associated with adaptation measures. We have selected measures relevant for the Carpathian region, yet have not restricted ourselves to studies from the region. Examples of costs of ecosystem-based measures from the reviewed studies are:

- Floodplain restoration:
  - 7 km of river = EUR 6.3 million (Upper Drava case study)
  - 10 km river reconnected to its side arms, affecting 500 ha = EUR 2 million (Regelsbrunner Au case study);
- Land acquisition to conserve habitats of rare species in California, USA: $2,400 - $62,000 per ha (1,800 - 46,000 euro);
- The development of a plan to respond to drought at the U.S. state level: $50,000-$100,000 (37,000 - 74,000 euro).

Valuing the benefits of adaptation measures, and of eco-system based adaptation measures in particular, is difficult. Benefits are diverse and often go beyond direct monetary value. The CarpathCC project therefore choose to assess the benefits of adaptation measures in terms of ecosystem service (ES) delivered by the Carpathian ecosystems (Arany *et al.*, 2013a). In line with this approach, measures such as High-Nature Value payments and Payment for Ecosystem Services schemes were explored in a qualitative assessment based on expert judgment, literature search and information gained from stakeholders during CarpathCC workshops. For the adaptation measures studied in more detail, no negative changes in ecosystem services due to the selected adaptation measures were identified. All adaptation measures do affect the services in a neutral or positive way. Measures were found to be able to enhance the production of traditional farming and forestry. In addition, benefits were reported for regulating services, such as genetic/species diversity and water purification. A smaller effects was found on cultural ecosystem services. Although the measures will enhance aesthetic pleasure due to landscape conservation, no (direct) effects were expected to tourism activities in the area (number of overnights, frequency of visits, spending).

The assessment of ecosystem services was performed for a set of sixteen ecosystem services in different habitat types. Results were found to be highly location specific and difficult to integrate over ecosystem services. Figure 7-1 provides an illustration of the importance of ecosystem services provided by the specific habitat type 9410 (forest habitat: Acidophilous Picea forests of the montane to alpine levels (Vaccinio-Piceetea)) (Arany *et al.*, 2013a).

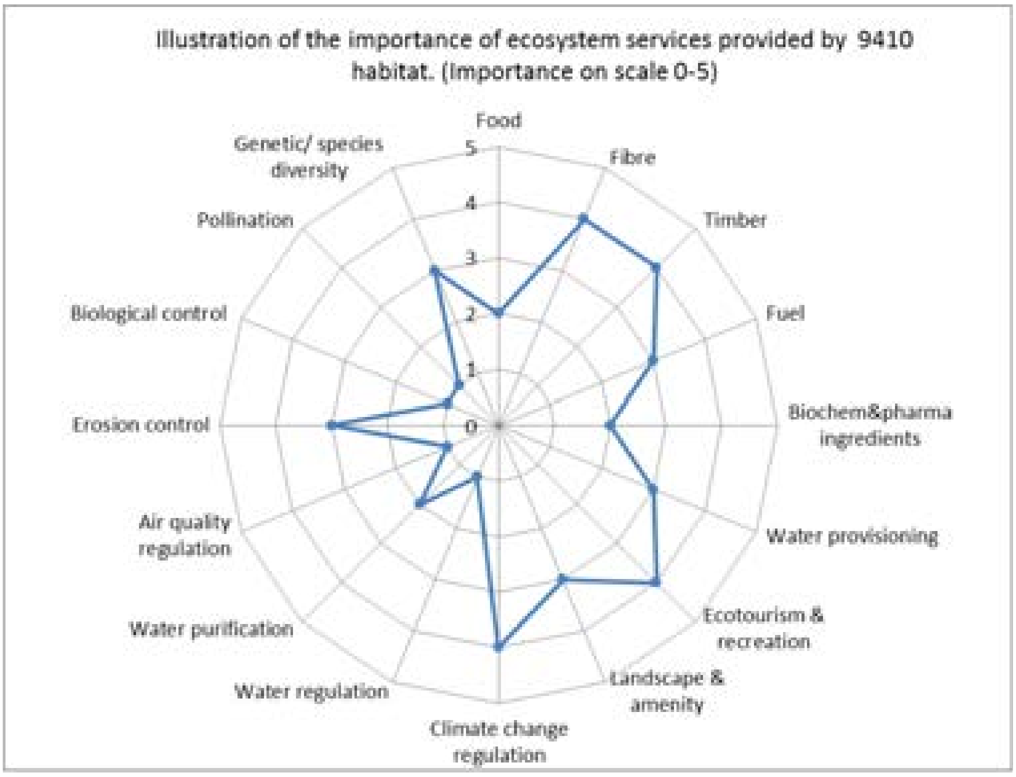

Figure 7-1 *The importance of ecosystem services provided by forest habitat: Acidophilous Picea forests of the montane to alpine levels (Vaccinio-Piceetea) – 9410.*

Relevant cost data could be obtained for wetland restoration, agri-environmental measures and habitat restoration. Cost and benefits that were identified for a set of specific adaptation measures are presented in the next section.

7.5 Case examples of adaptation measures for the Carpathian region

This section offers specific case examples of adaptation measures, along with their cost and benefits that have been discussed for specific locations in the Carpathian region.

7.5.1 Adaptation option water resources: rainwater harvesting - improving water storage capacity and erosion control

Description

Increasing the water-holding capacity of the soil and harvesting precipitation in places where it falls are employed as anti-flood measures. Kravcík *et al.* (2007) discuss water harvesting techniques in support of what they call a 'new water paradigm' (see Figure 7-2 and 7-3). Interventions include creating terraces and protecting/restoring infiltration areas. Typically water harvesting combines more technical interventions such as the building of depressions or small dams with biological elements such as the use of vegetation-borders, grassy belts, and belts of shrubbery and trees.

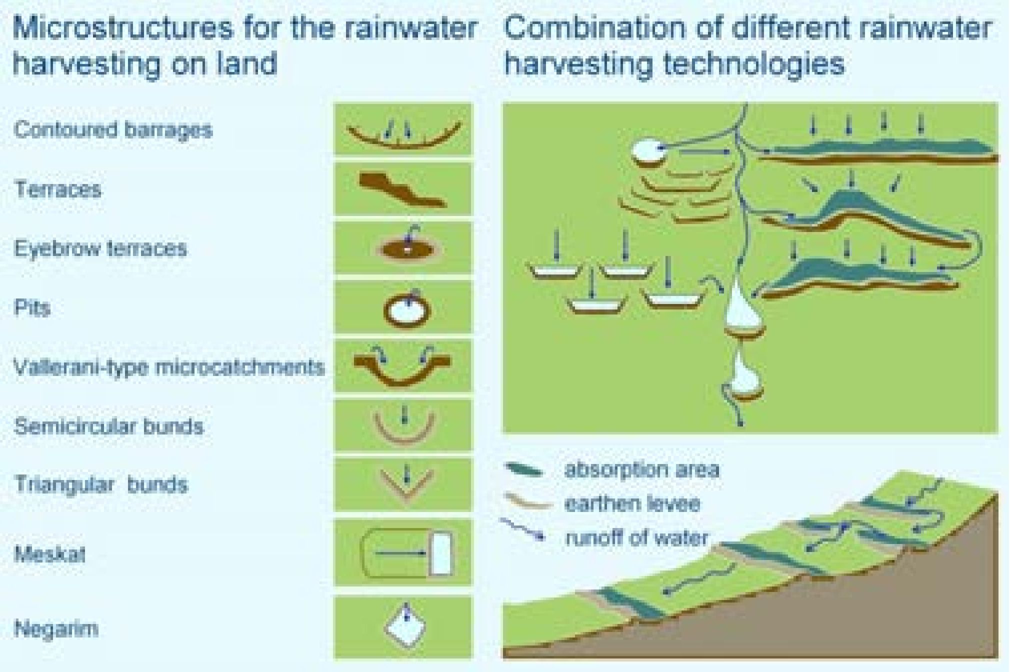

Figure 7-2 *Examples of rainwater harvesting (source: Kravcík et al. (2007)).*

Figure 7-3 *Experimental rainwater harvesting installations in the Tatra (Photo / Source: Kravcík et al. (2007)).*

Implementation time

5-10 years. In the case of Slovakia, effect of measures are expected to become visible relatively soon (10 to 20 years) after implementation.

Policy issues

Often requires an intersectoral and integrated approach to water management and economic policies (including agricultural and forestry policies) which influence the runoff conditions of an area.

Success and limitation factors

Local reappraisal of drainage relations and the design of anti-erosion and water conservation measures can require new zoning and landscape planning. Local success depends on rapid financing of prepared projects.

Actors involved

Regional administration, forest authorities, property owners, landscape engineers and planners.

Cost benefit

The average costs for the preparation and implementation of comprehensive flood prevention measures based on water conservation / harvesting and anti-erosion measures in a unit of land depend on its character, morphology and the need for intervention. Kravcík *et al.* (2007) report that there are diverse measures which combine natural materials and engineering that do not require massive investments. On the contrary, they are undemanding and utilize local materials and the local labour force. The maintaining of measures implemented in a territory could be handled by landowners, which would cost only a relatively small amount and would create primary and subsequently secondary employment. The average costs for implementation of comprehensive flood prevention measures based on water conservation / harvesting and anti-erosion measures for a square kilometre of land represent 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). The approach is less expensive than other solutions which have already been tried or proposed (Kravcík *et al.*, 2007).

On the benefit side, overland 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, can reduce the risk of natural disasters like floods, droughts and fires, can stabilize the climate and strengthen biodiversity and can become a component of economically sustainable development programs.

7.5.2 Adaptation option water resources: Adjusting the operation of existing water infrastructure

Description

Adjusting the operation of existing infrastructure can help manage climate changes in climate variability. In particular periods of high and low rainfall can be anticipated.
Changed management of existing infrastructure is considered a soft adaptation measure, as no additional infrastructure needs to be built.

In the upper part of the Romanian Târnava Marė region in the south-east of the Carpathian mountain chain the Zetea dam and reservoir are located. In the region the natural disaster mostly affecting the population and causing economic loss is flooding. Most floods are caused by rainfall events. The main vulnerability in this area results from the increasing frequency of extreme events due to combination of natural and anthropogenic factors. Landslides and floods are projected to increase. Another threat is the increase of the number of dry spells (see Figure 4-2 for projected changes in discharge) in which the minimum flow cannot be maintained causing damage to in-stream and riparian ecosystems (Zsuffa *et al.*, 2013). This adaptation measure proposes to adjust the release strategy of the Zetea dam and reservoir to cope with flood and drought events. Already the dam has substantial effects on discharges downstream because it is used to augment low flows (release of minimum discharge in drought periods) and for flood protection (cutting peak flows). Table 7-2 presents the reservoir’s capacity, which determines the management options (Zsuffa *et al.*, 2013). Presently the reservoir is mostly operated for flood protection: whilst filling the Active Capacity, up to 50 m^3/s are released (Flood Threshold 1). Beyond the Active Capacity, whilst filling up to Flood Capacity 1, the discharge can be increased up to 550 m3/s (Flood Threshold 2). Once Flood Capacity 1 is reached, another 11.7 million m^3 is added (Flood Capacity 2) and 550 m3/s are released whilst further info is stored. The adaptation measure proposed here is to increase the active capacity (from 14.4 million m^3 to 17.9 million m^3). Note: conversely, this measure reduces the flood protection storage (from 18.4 million m^3 to 14.9 million m^3).

Table 7-2

Overview of capacity of reservoir Zetea.

	Volume [million m^3]	Sum Volume [million m^3]	Description
Dead Storage	2.1	2.1	Volume below reservoir outlet. Water cannot be released from this part of the reservoir
Active Capacity	14.4	16.5	Volume used for normal reservoir operation. Water is released to keep the Minimum Discharge Q_{Min} downstream of the dam
Flood Capacity 1	18.4	34.9	
Flood Capacity 2	11.7	46.6	
	Discharge [m^3/s]		
Minimum Discharge	0.55		Minimum discharge from reservoir (env. flow)
Flood Threshold 1	50.0		Released when Flood Capacity 1 is reached
Flood Threshold 2	550		Released when Flood Capacity 2 is reached

Figure 7-4 *Aerial picture of Zetea dam and reservoir, Târnava Marė region.*

Implementation time

1-5 year

Policy issues

Dam operation policy is changed. Benefits are expected in meeting minimum flow requirement in line with the European Water Framework Directive.

Success and limitation factors

The measure is realised on account of reduced flood protection storage. The assessment showed that under the employed climate change scenarios the flood protection function was not compromised. The water release strategy could be further optimised using short and medium term weather forecasts.

Actors involved
National administration, municipalities dependent on flood protection and fresh water supply (agriculture, drinking water).

Cost benefit
The costs of changes in the management regime of the reservoir are assumed negligible.

Benefits in terms of increased water storage and maintaining low flow have been assessed using the eco-hydrological model ‘Soil and Water Integrated Model’ (SWIM) (Krysanova *et al.*, 1998) together with a reservoir module developed for SWIM (Koch *et al.*, 2013). The model was driven by datasets produced within in the EU FP6 WATCH project (http://eu-watch.org/). Figure 7-5 shows how the adapted reservoir-filling regime at the start of the drought period enables the release of water for a longer period of time (as an example the figure shows results for scenario HadCM3Q0-MPI). Further analysis of the model results showed that the proposed increase of active storage capacity would reduce the total number of days with outflow below minimum flow by 20% (443→356) in 2021-2050, and by 66% (247→83) in 2071-2100. Note: the SWIM model could only be calibrated for more downstream location, encompassing a larger catchment area, as for the reservoir no measured discharge time series were available. Thus model results have to be treated with extra care. In addition, the number of dry days and the benefit if adapted reservoir operation strongly depend on the climate model scenario used.

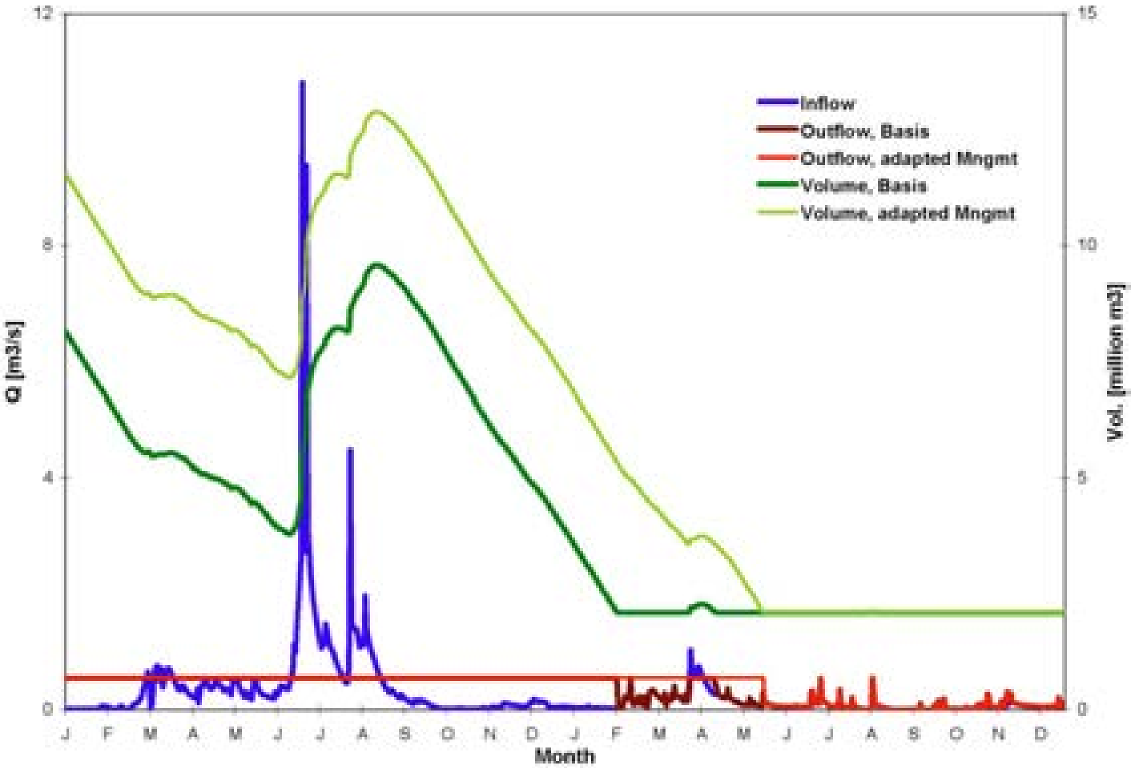

Figure 7-5 *Simulated inflow, discharge downstream (outflow) and filling of Zetea reservoir (river Târnava) for current (basis) and adapted management (GCM-RCM-combination HadCM3Q0-MPI (drought conditions)).*

Services derived from changes in the storage regime include:
Regulating services: optimised reservoir operation to attenuate the impacts of the future frequency of extreme events. Avoided impacts include loss of life, economic loss and pollution of surface waters by waste flushed from banks. There has been no further quantification of these benefits in relation to specific dam management regimes.

Provisioning services: sustaining low flow avoids projected damage to in-stream and riparian ecosystems. In addition, increased storage to cope with periods of drought provides benefits for agriculture and drinking water. The quality of the fresh water the upstream reservoir is high.
Cultural services: protection of traditional landscapes and villages from extreme events, including landslides.

7.5.3 Adaptation option forestry: Compensation scheme for forest protection

Description
Compensation schemes, such as 'Payments for ecosystem services' (PES), describe the practice of offering incentives to foresters in exchange for managing their land in a more extensive way. One the one hand, the environmental quality will increase, at the expense of a reduction in profit. For this loss of profit, the landowner is 'compensated'. In a PES scheme, the compensation payments are tied to the provision of some sort of ecological service. One of the measures are reductions of the share of spruce and enrichment of present species composition by fir, larch and mountain sycamore. These interventions may have positive effect of forest`s resilience; considering the almost 80% share of spruce in the Rodna-Maramureş region. Extended cutting regimes is another example of ecological services. This measure has been discussed in the CarpathCC project for the Rodna-Maramureş region.

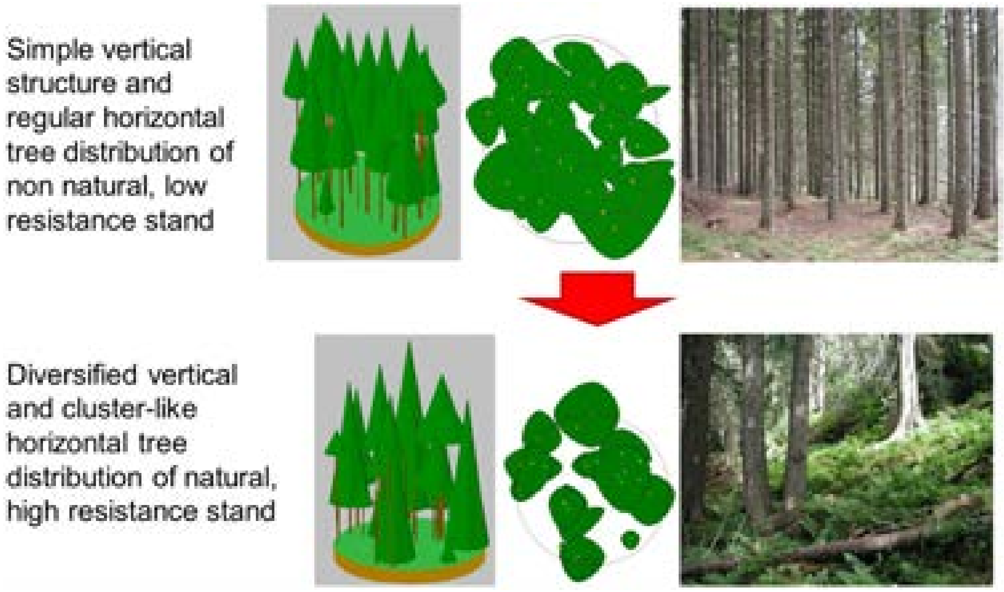

Figure 7-6 *An extended cutting regime leads to adaptation of forest structure (source: CarpathCC Project presentation).*

Implementation time
5-25 years.

Policy issues
Sustainable forest management.

Success and limitation factors
In Romania, the possibility to implement compensation schemes is limited because of underfunding. Compensation schemes should be, at least, implemented for Protected Areas (PA), because for many PAs, forests are private property. In Rodna, the total surface is 23.000 hectare of forest, from which 40% is protected area and 60% is managed forest. Applying the PES scheme to the 40% protected forest corresponds to 9,200 ha.

Sustainable forest management is crucial for effective provision of ecosystem services. In theory, forest ecosystems within Rodna area are managed according to the forest and parks management plans, but in reality these plans are not always fully enforced. There is no compensation for harvesting restrictions within private forests and owners therefore have no incentive to restrict harvesting (Popa and Bann, 2012). Also, ineffective enforcement of the legal framework will result in on-going illegal logging and hunting. The absence of an equitable system of compensatory payments will encourage local forest owners to overcut. The Carpathian forests face a range of pressures including the overexploitation of forest resources through logging (illegal logging).

Actors involved
Ministry of Environment and Climate Change; National Forest Agency-ROMSILVA; Administration of Rodna Mountains National Park.

Cost benefit
Costs: No costs of the measure could be assessed, as PES schemes are not yet applicable in the Romanian Carpathians. Lack of financial resources may cause that national adaptation strategies remain in declarative form only.

Benefits: The adaptation measure ‘compensation schemes’ is expected to benefit the ecosystem services, affected by climate change in the period 2020-2050, in the following way:

- As PES schemes are combatting overexploitation and illegal logging, both enforcing the negative effects of climate change, the implementation of a PES scheme can have a positive effect on the recovery of this ecosystem;
- *Provisioning services:* Initially, PES schemes lead to less timber production (managed logging, establishment of ‘no go area’s’, ….). Although less provisioning services are delivered to society, there are no income effects for foresters, thanks to the payments. The indirect effect will be positive as sustainably managed forests (e.g. diminishing monotonous picea plantations) will be better protected against pest outbreaks caused by extreme weather (e.g. storms). The climate change induced shift from timber production to fibre/firewood production will be reversed via PES schemes. More sustainable timber production will offering additional added value;
- *Regulating services:* Increased temperature may have positive effect on carbon sequestration and climate change mitigation in higher elevations; this function can be however compromised by more frequent wind throws, snow damages and bark beetle outbreaks (Kurz *et al.*, 2008). The effects of the adaptation measure will thus be difficult to assess because of the double impact of climate change. Anyway, the PES scheme implementation can produce a better organization of the forestry sector within the Rodna-Maramureş region. Reductions in forest cover and even clear cutting in some cases has resulted in a decrease in the ability of ecosystem to retain water and protect against soil erosion. PES schemes can stimulate erosion control. Also genetic/species diversity will be enhanced, given biodiversity is one of the focal points of PES schemes;
- *Cultural services:* PES schemes can enhance the aesthetic values, given more forest diversity and better protection against pest outbreaks. Although these events may not influence the tourist’s choice to spend their holiday in the area. For example, the pest outbreak in the High Tatra Mountains, as a result of the wind thrown in 2004, did not result in less tourists.

7.5.4 Adaptation option for natural grassland: The development and support of ecosystem monitoring systems

Description
The goal of this measure is to improve the use of grassland monitoring data for the assessment of grassland vulnerability to climate change and dissemination of this information to all stakeholders. Currently several techniques are applied for the monitoring of the grasslands in the High Tatra (Slovak Tatra Mountains) including advanced techniques such as remote sensing through satellites as well as more traditional techniques such as ‘two land plots’.

This experience can be used to monitor the climate change impacts and project the further changes and development of sensitivity. An important goal is also raising awareness among the decision makers and general public. The expected impact of the measure is substantially increased knowledge basis on climate change and its impacts on the mountain ecosystems on the medium altitudes in Europe. Awareness of the general public will also be increased.

Cost benefit

Costs: No costs of the measure could be assessed. Monitoring is a continuous process. Acquiring new information on the regular basis will represent the major costs for the adaptation measure. Other relevant cost components are investments in hard- and software for developing the models and costs of the conferences, workshops, and other activities related to exchange scientific information.

Benefits: The 'development and support of ecosystem monitoring systems' is not expected to impact the climate change affected ecosystem services. Though there is in that sense no direct impact of the measure, accumulation of new knowledge is expected to affect positively the process of modelling. Better projections with less uncertainty allow effective decision making. One more indirect benefit of the monitoring systems with the appropriate set-up is an early warning system on the occurrence of grassland wild fires. In addition, the monitoring of grasslands of High Tatra may lead to better understanding of processes to benefit Regional Climate Modelling elsewhere.

7.5.5 Adaptation option for grassland: the restoration of degraded grasslands with high biodiversity value and preserving existing small grasslands and pastures

Description

This measure is being developed for the Bükk region, Hungary (Figure 7-7). The area 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. It was on the way of natural reforestation. The KEOP project aims at restoring this site as 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. This was followed by the mechanized crushing of stalk left in the soil. The remaining land is being preserved as grassland, which requires mowing on a regular basis (grazing will not be allowed because of the drinking water wells downstream in the valley). In the final stage of the KEOP project, fruit trees are being planted. Planting of traditional, autochthonous (endemic) fruit trees is envisaged. These species are much more resistant against environmental stresses (like climate change) than the new breeds. In fact, as Zoltan Ilonczai (Bükk National Park) emphasized, this is the way how the negative impacts of climate change are aimed to be counteracted. The numbers of fruit trees to be planted:

- apple: 159
- quince: 494
- cherry: 2
- pear: 28
- plum: 112

Figure 7-7 *The karstic plateau of the Bükk (photo by János Scheffer).*

Cost benefit

Investment costs: The extents, durations and costs of the interventions envisaged by the KEOP project are summarized in the following table:

Table 7-3

Direct costs for measures in the KEOP project for the period 2013-2015.

Measure	Extent [ha]	Costs [HUF]	Costs [euro]	Costs per ha [euro]
Removing invasive trees (acacia)	4	2,000,000	6,807	1,702
Manual clearance of bushes and shrubs	14	5,600,000	19,061	1,361
Crashing of stalk left in the soil	18	1,800,000	6,127	340
Mechanical mowing	34	4,760,000	16,202	477

Mowing has been repeated on the site during 3 years period of the KEOP project. This explains why the total area of mowing is higher than the total area of the site. The interventions do not cover the entire 25.7 ha area of the study site. Mowing will (should) continue after the indicated three years long period; however that will not be financed from the budget of the KEOP project.

The National Park purchased a total area of 4.2 ha within the frame of the KEOP project for 1,702 euro/ha. Thus, the total cost of land purchasing was 7,148 euro. The costs of planting fruit trees: 3,745 euro; which corresponds to 4.29 euro on average per fruit tree.

Maintenance costs: The National Park intends to maintain the grassland in the desired state in a sustainable and cost-free way. The major issue is regular mowing. The plan is to motivate local farmers and people to come to the area and mow it in return for the hay that they can keep and use it for their own purposes. If this does not prove to be sufficient, then the NP will have the mowing carried out by unemployed people engaged in the public labour service. This public labour service is actually a cost-free solution for the National Park.

Benefits:

Planting of fruit trees started in April 2013 and was completed in October 2013. The estimated annual yields of these fruit trees is 37,798 euro. Mowing will generate hay. The amount of hay per hectare will not be relevant, compared to more intensively managed grasslands. The mean annual hay yield of natural grasslands in Hungary is 1.7 t/ha. Counting with 25.7 ha, this means 43.69 t hay per year. The price of annual hay production in the case study area will be 1,889 euro/year.

The adaptation measure ‘Supporting and implementing HNV’ is expected to impact the ecosystem services in the period 2020-2050, in the following way.

- *Provisioning services:* KEOP aims to improve the water provisioning service of the area. Turning the area into an open grassland will increase the infiltration in the area for the benefit of drinking water supply. Mature forests with dense canopy (the final stage of succession in case if the KEOP project were not implemented) have a high capacity of interception. It can be as high as 40% of the precipitation on open surface. Short rainfalls during the growing season may even be completely intercepted and evaporated to the atmosphere by the canopy. In case of open grasslands, large parts of these rains infiltrate into the soil thus contributing to near-to-surface groundwater, servicing nearby wells. In addition, forests have higher evapotranspiration rates than grasslands due to the deeper rootzone and to the higher transpiration rates of trees and bushes. This potentially further competes for groundwater resources available for drinking water supply. The exact impact on the water balance will depend on the location and would have to assessed (Arany *et al.*, 2013a). The opportunity of mowing offered by the National Park is beneficial to local farmers being allowed to use the hay for their own purposes. This will support the food provisioning service. Locals will also be allowed to harvest the fruit trees and take the fruits. This will improve the supply of homes and families with healthy fruits. The area may also provide space for some medicinal plants;
- *Regulating services:* One of the objectives of the KEOP project is to improve the pollination capacity of the case study area. Grasslands are excellent habitats for key pollinators such as butterflies and bumblebees. These pollinators will pollinate the newly planted fruit trees within the case study area, as well as the existing orchards in the pollination buffer. The on-going natural reforestation process would sooner or later destroy most of the protected, valuable plant species. One of the objectives of the KEOP project is to preserve these species by restoring the area as grassland (grasslands are excellent habitats for insects). The aim of grassland restoration is to maintain this function of genetic/species diversity maintenance. Moreover, the fruit trees will function as genetic reserves of traditional, autochthonous species. Grafts will be given to farmers, NGO-s from all over the region and the country (also from abroad) in return for participating in the harvesting work;
- *Cultural services:* The tourism sector is expected to benefit from this project. Before the KEOP project, the area was already a target for tourists and local people for walking. After the project, the National Park plans to create an about 2 km long tourist path in the area. Eco-agro-tourism is envisaged through organized excursions guided by experts from the NP. This planned tourist path will be integrated into the existing tourist paths of the region. Hotels and restaurants in the region will also slightly benefit from this touristic initiative. The habitat is strongly related to traditional agricultural practices preserving high species and landscape diversity. As a result the ecosystem service “Landscape & amenity values” will be strengthened.

7.5.6 Adaptation option for wetlands: Maintenance of alluvial forests

Description

Riparian, alluvial forests are the natural type of vegetation along streams and rivers, and are strongly influenced by flooding and high groundwater levels. Due to their small-scale mosaic site conditions, riparian forests count among Europe’s most species-rich habitats. Near-natural riparian forests have virtually disappeared from Central Europe as many riparian forests 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 of typical tree species, near-natural management, securing of existing areas and maintaining structures associated with the riparian forests (e.g. small water bodies). This measure is developed for the wetland in Divici Pojejena, Iron Gates national park, Romania (Figure 7-8).

Figure 7-8 *Divici Pojejena Wetlands.*

Implementation time

5-10 years.

Policy issues

Flood protection, climate change regulation.

Cost benefit

Costs: The costs for maintenance of alluvial forests are estimated about 1,018 euro / ha for a 2 years period (according to Caras-Severin Environmental Protection Agency. 800 euro / ha for the first year of the project and 218 euro / ha for the second year). The area is about 55 hectares and includes 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 55,990 euro.

Benefits: The adaptation measure “maintenance of alluvial forests” is expected to impact the ecosystem services, affected by climate change, in the following way.

- *Provisioning services:* Maintenance of alluvial forests is expected to have a slight positive effect on fishing, as the riparian borders of the forest can act as spawning grounds;
- *Regulating services:* Expanding & maintaining the area of alluvial forest will benefit climate change regulation, as forest all well known for their carbon sequestration. The adaptation measure will have a positive effect on the recovery of the ecosystem service ‘water purification’, but no full recovery. The alluvial forest might purify the water by reducing quantity of nutrients and pollutants. Erosion control will be enhanced, given the capacity to prohibit sediment transport to the Danube. The strongest positive effect is expected for ‘genetic/species diversity’, with full recovery of the ecosystem services. This measure has proposed aiming at extension of the wintering and nesting habitat for the pygmy cormorant and ferruginous duck (protected species);
- *Cultural services:* The adaptation measure is not expected to have an effect on the recovery of the ecosystem service. The warmer climate may bring more tourists in the area by extending the summer season. The cultural service ‘cultural, landscape & amenity values’ will slightly increase due to a more diverse landscape, offered by the ‘healthy’ alluvial forests.

7.5.7 Adaptation option for agriculture: Supporting and implementing high nature value farming

Description

This adaptation measure ‘supporting and implementing high nature value farming (HNV)’ includes those types of farming activity and farmland that, because of their characteristics, can be expected to support high levels of biodiversity or species and habitats of conservation concern[6]. The measure has been explored for the Tarnava Mare region in Romania. The Romanian Government has implemented a High Nature Value Grassland agri-environment measure (AEM) as part of the Romanian 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 in this measure can also apply for the Traditional Farming option whereby additional payments can be obtained in return for not using any mechanization (Figure 7-9).

Figure 7-9 *Traditional agricultural practices in the Tarnava Mare region (source: www.fundaţia-adept.org).*

Implementation time

1-5 years.

Success and limitation factors

At this moment it was found not possible to assign agri-environmental support to the selected area of grasslands (5,895 ha) as these grasslands are often common grazing grounds, without property titles. The payments will help the farmers to meet the possible reduction in products quantity but more incentives are needed to preserve a competitive market. Those products (milk, wool, ...) are competing on the market with similar products coming from intensive exploitation, which is a considerable disadvantage. At the same time implementation of the agro-environment payments will impose conditions which may lower the quantity of grassland production utilized by farmers (limitation of hay cutting rates and the extensive grazing limits).

Recently some successful incentives have been set up in villages in the Tarnave region. An example good practice is from the dairy sector. The dairy sector in the Tarnava Mare area, as well as in most part of the Transylvania, is in a state of collapse. The number of cattle decreased in the last years due to the lack of interest for milk market. ADEPT Fundation helped the small-scale producers from three villages (Saschiz, Daia and Danes) to improve their milk collection points and also with other activities

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[6] For a set of indicators describing HNV in more detail consult http://www.efncp.org/policy/indicators-high-nature-value-farming

to increase the interest for the buyers. Within six months the three villages have had their milk collection reinstalled and the fall in cow numbers was reversed. It was concluded that ”without a market, agri-environment payments alone are obviously not sufficient to halt the collapse of the milk sector” (Page *et al.*, 2010).

Another measure to be combined with agri-environment payments, is the creation of a regional brand. By creating brands, such as the Tarnava brand, see Figure 7-10, communities, often assisted by NGOs, could successfully improve markets for local products.

Figure 7-10 *Regional brand for the Tarnava Mare area, which acts as a quality mark for local products. Created by ADEPT Fundation.*

Actors involved

Farmers, national and regional government.

Cost benefit

Costs: Farmers in the Tarnava Mare area can be subsidised by the following amounts upon fulfilling the agri environmental conditions.

Table 7-4

Unit costs of the adaptation measure for Tarnava Mare.

Measure	Amount	Beneficiaries
Agri-environment package 1: HNV grasslands	124 euro/ha year	Farmers
Agri-environment package 2: Traditional farming	58 euro/ha year	Farmers

Benefits: The adaptation measure “Supporting and implementing HNV” is expected to impact the ecosystem services, affected by climate change in the period 2020-2050, in the following way:

- *Provisioning services*: In the short run, the measures seems to limit the output of meat, milk, wool, etc., given the limitations in stocking rate & cutting regime. Those conditions can be offset by the quality and the conservation of the grasslands. In the long run, farming is preserved via sustainable grassland management. The majority of the area is under subsistence or semi-subsistence type farming, and the meat, dairy products and honey are thus an essential source of food for the local population. The measure will help continuing their production.
  Potentially, after the implementation of the measure, a good state of the ecosystem will be provided and the Tarnava Mare area may be able to obtain ingredients for biochemical or pharmaceutical products. Wild plants hold a valuable source of biochemicals and pharmaceuticals. Today, the use and knowledge about these plants is decreasing as they are replaced by synthetic substances. However, a wide range of plants are still used medicinally: Greater Burdock (*Arctium spp*.), Marsh Mallow (*Althaea officinalis*), St John's-wort (*Hypericum perforatum*),Yarrow (*Achillea millefolium*), and Centaury (*Centaurium erythraea*);
- *Regulating services*: The potential to sequester carbon by improving grassland conservation, management and restoration of degraded grasslands is substantial, approximately of the same order

as that of forestry sequestration (Hönigová *et al.*, 2012). Due to the incertitude in climate change effects on carbon stock/sequestration, a conservative approach is here also advisable. Semi-natural grasslands with limited grazing will contribute to soil conservation and prevent soil loss due to water and air erosion. One of the main objectives of HNV farming is the maintenance and increase of species and habitat diversity. It is well documented that a more intensive application of machinery, fertilisers, biocides and livestock reduces the opportunities for wild life on cropped and grazed land (Hönigová *et al.*, 2012). The HNV measure forms a good counterweight to the predicted species shifts of climate change. For example, grassland butterflies thrive on sustainably managed grassland with many wild flowers providing either nectar for adult butterflies or larval food plants. Protection and low-intensity management of HNV farmland would help to stem grassland butterfly losses and could help to start their recovery;

Cultural services: As a side effect of the agri-environment measure, tourism will continue to develop, due to the unique landscapes, hospitability of rural inhabitants, conservation of tradition, and the diversity of rural tourist resources. The adaptation measure initiates a ‘multiplier effect’, creating via tourism an extra form of ‘payment’ to local people for landscape conservation. The results of the measure will also improve the landscape & amenity values of the region. Aesthetic/spiritual values are unrecognized and uncompensated side effects of conservation of these landscapes. According to the limited number of published data available on the recreational value of different grassland habitats or other agriculturally used habitats, evaluation of recreational suitability is based on people´s perception and aesthetic appreciation of, amongst others, vegetation. It has been shown that this must be correlated with plant species richness, which in itself is attractive to humans. Therefore, habitats providing high species richness such as HNV grasslands are classified as highly suitable for recreation, more than intensively used habitats like intensively managed meadows, arable land and fields (Hönigová *et al.* (2012), http://www.teebweb.org/wp-content/uploads/2013/01/Survey-on-grassland-ES_2011_

8 Stakeholder interaction

The Third Meeting of the Conference of the Parties (COP3) to the Carpathian Convention (Bratislava, Slovenia, 2011) approved the Terms of Reference for the Working Group on Adaptation to Climate Change by its Decision COP3/15. This Working Group aims to support the Parties to the Carpathian Convention by providing advice on adaptation to climate change in the Carpathian region. The working group will debate the available information on vulnerability to climate change impacts in the Carpathian Region, and provide guidance and recommendations for the development of policy proposals in line with the objectives of the Carpathian Convention and the European Commission’s White Paper on Adapting to Climate Change.

The European CARPIVIA project supported the working group by providing access to state-of-the-art information on vulnerability in the Carpathian region and on potential adaptation measures. Most substantially, CARPIVIA supported the working group in developing a Strategic Agenda on Adaptation to climate change in the Carpathian Region to be adopted the 2014 Conference of the Parties (COP) to the Carpathian Convention. The working group was the main mechanism for stakeholder interaction of the CARPIVIA project. In addition results of the project will be disseminated by a dedicated website and through presentations at workshops and conferences in the region (see Annex B).

Table 8-1

Planning for Adaptation working group.

When	What
Oct 2011	Invitation to participants of the Carpathian Convention to nominate members for the Adaptation working group
Nov 2011	Interviews with participants to assess their expectations and opinions. Special attention to what impacts of climate change are (un)acceptable
Febr 2012	First adaptation working group meeting (location: Brussels) Input: summary interim report. The main goal is to identify: • Impacts of climate change that are of particular relevance for the Carpathian Convention; • Adaptation measures that are of particular relevance for the Carpathian Convention. These impacts and adaptation measures can be appraised in more detail by the CARPIVIA project. Results of which will be the input of a second session of the working group.
30 May - 2June2012	Presentation of CARPIVIA results at the 2nd Forum Carpaticum. Possibility to meet with working group members as appropriate
23 - 24 October 2012	Second adaptation working group meeting (location: Eger) The main goal is to evaluate progress towards the strategic agenda and information system.
12-13 March 2014	Third adaptation working group meeting (location: Vienna) The main goal is to evaluate project outcomes and formulate policy recommendations with respect to adaptation to the impacts of climate change. Recommendations are to benefit national and regional authorities of the Carpathian Region and the Carpathian Convention in particular.
September 2014	Workshop on climate change adaptation and presentation of CARPIVIA results at the 3rd Forum Carpaticum in Lviv, Ukraine. Workshop hosted together with the Carpathian Convention.

9 Strategic Agenda on Adaptation to Climate Change

STRATEGIC AGENDA on

ADAPTATION TO CLIMATE CHANGE

in the

CARPATHIAN REGION

CARPIVIA
CARPATHIAN INTEGRATED ASSESSMENT OF VULNERABILITY TO CLIMATE CHANGE AND ECOSYSTEM-BASED ADAPTATION MEASURES

CARPATHIAN CONVENTION

This revised draft version dates April 2014

STRATEGIC AGENDA on ADAPTATION to CLIMATE CHANGE in the CARPATHIAN REGION

Introduction

This Strategic Agenda is developed by the Working Group on Adaptation to Climate Change under the Carpathian Convention with support from the CARPIVIA[7] project. The aim of this strategic agenda is to assist Member States of the Carpathian Convention, local and regional authorities and other stakeholders involved in management of the Carpathian region in formulating responses to climate change as a contribution to securing sustainable development of the Carpathian region.

The draft Strategic Agenda on Adaptation to Climate Change has been discussed in a number of meetings and workshops with Country representatives and observers to the Carpathian Convention as well as interested stakeholders.
The Strategic Agenda holds recommendations for policy development, institutional change and ecosystem based adaptation measures and by adopting this Strategic Agenda the Conference of the Parties to the Carpathian Convention endorses the proposals formulated in this Strategic Agenda and 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 adaptation strategies to adapt to climate change impacts and to mitigate adverse impacts of climate change.

The challenges posed by climate change to the Carpathians as shown by the reports of the CARPIVIA and CarpathCC[8] projects illustrate that the impacts of Climate Change on the Carpathian region are significant and that current management should be reconsidered. Adaptation to climate change calls for strengthened international cooperation in the Carpathian region and in accordance with its mandate, the Carpathian Convention is well placed to stimulate and coordinate the efforts to adapt to climate change as a contribution to sustainable development of the Carpathian region. In the light of the challenges, the evaluation of the Working Group in 2013 and the mandate of the Carpathian Convention, the Working Group recommends to seek for possibilities to establish the Working Group as a permanent Working Group. In agreement with the mandate of the Carpathian Convention, the aim of the Working Group would be to guide the implementation of the Strategic Agenda and provide advice and direction to the Carpathian Convention and its Contracting Parties on climate change adaptation policies and measures.

1 Opportunities exist to steer the Carpathian region onto a sustainable, climate-proofed path. This document aims to assist governments and other stakeholders in formulating responses to climate change towards this goal. The document offers a draft Strategic Agenda on Adaptation to Climate Change as a basis for consultation[9] with signatories and observers of the Carpathian Convention as well as interested stakeholders.

<u>What this document is:</u>

2 A Carpathian-wide, strategic policy guidance with suggestions for future policy, programming and institutional directions to move the Carpathian Space towards a climate-proofed future. Generic-level measures are given, together with other opportunities for action, by way of illustration. In particular, the document is a support to assist the Working Group on Adaptation to Climate Change

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[7] Carpathian Integrated Assessment to Climate Change and Ecosystem Based Adaptation Measures; Tender DG ENV.D.1/SER/2010/0048

[8] Preparatory action on climate in the Carpathian region – Framework contract for in-depth assessments of vulnerability of environmental resources and ecosystem-based adaptation measures; Framework Contract Number DG ENV.D.1/FRA/2011/0006

[9] The consultations are to result in a Strategic Agenda offered by the members of the Working Group on Adaptation to Climate Change to the Carpathian Convention for approval by the Carpathian Convention Implementation Committee before the Fourth Meeting of the Conference of the Parties to the Carpathian Convention (COP 4) to be held in Czech Republic in 2014.

(Climate Change WG), established at COP3 in May 2011, fulfil its tasks including the development of policy proposals in line with the European Commission's White Paper and the Carpathian Convention[10]*.*

What this document is not:

3 A detailed analysis of reference conditions or climate change scenarios, nor a climate change adaptation strategy, nor a programme-of-measures, nor a prescriptive list of what is required.

This document is accompanied by:

4 Annex: Matrix of Policy Opportunities for Climate Change Adaptation Measures in the Carpathians, *listing possible adaptation measures, policy linkages, actors involved, and forthcoming funding opportunities with timelines of decision-making.*

Background: Climate Change in the Carpathians[11] and What does Adaptation Mean?

5 According to the IPCC's 4th Assessment Report (2007) the great majority of organisms and ecosystems are likely to have difficulty in adapting to climate change, with central Europe likely to be one of the hardest hit regions[12]. Regional climate change projections suggest more irregular rainfall and a warmer climate in the Carpathian basin. According to the endorsed Working Group II contribution to the Fifth Assessment Report of the IPCC's "climate change will increase the likelihood of systemic failures across European countries caused by extreme climate events affecting multiple sectors (medium confidence). (..) adaptation can prevent most of the projected damages (high confidence)."

Studies of temperature change over the Carpathian Basin, summarised by CARPIVIA, largely agree increases in temperature. The Carpathian mountains will experience an increase between 3.0 ºC in the north-western part to 4.5ºC in the south during this century.

6 Model studies largely agree in projecting a small increase of winter precipitation and a significant decrease of summer precipitation. Although the mean annual values of precipitation will remain almost constant, decreases in summer precipitation are projected of above -20% and increases in winter precipitation in most areas of between +5 to +20% this century.

7 These changes will have profound consequences on the environment, on the economy, and on human health and wellbeing. These consequences will be summarised in the next section.

Climate Change Adaptation

8 The European Commission White Paper "Adapting to climate change; Towards a European framework for action" (COM/2009/147) calls for a more strategic approach to climate change adaptation across different sectors and levels of governance. This document, together with the Water Framework Directive, the Directive on Floods, the EU Water Scarcity and Droughts Strategy and the European Climate Adaptation Platform (Climate-ADAPT), form the core of EU policy on climate change and stress the importance of[13]:

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[10] The scope and mandate of the WG on Adaptation to Climate Change, according to the Terms of Reference, includes recommendations on policy proposals, follow-up projects including on adaptation measures, and a discussion on the cost, benefits and feasibility of adaptation measures, in particular on adaptive water management and ecosystem-based measures.

[11] Climate data taken from: DLO Alterra, 2011, Interim Report Task 2 CARPIVIA Project [Tender DG ENV.D.1/SER/2010/0048]: Preliminary Assessment vulnerability & potential adaptation measures, 82pp., Wageningen, Netherlands. Available online at http://www.CARPIVIA.eu/about-CARPIVIA/downloads

[12] IPCC, 2007, 4th Assessment Report, Chapter 12 – Europe, p.563.

[13] EU Guidance Document Number 24 – River Basin Management in a Changing Climate, technical report – 2009 – 040, Common Implementation Strategy for the Water Framework Directive (2000/60/EC), p.16, Brussels, Belgium.

- <u>Building resilience</u> against the added risk of climate change by acting on existing anthropogenic risk,
- Using a <u>cyclic management approach</u> to include increasing knowledge over time on climate change impacts, and incorporating this into a comprehensive information system for use in decision-making for adaptive management,
- Using the opportunity of <u>implementation of existing initiatives</u> to:
  - restore natural ecosystem function within catchments, in particular the ability of catchments to retain and slowly release water and to degrade pollutants,
  - reduce fragmentation and improve connectivity of habitats to allow species movements,
  - balance ecology and economic developments,
- Mainstreaming of climate concerns into other policy areas, programmes, processes and funding supports.

9 These elements constitute climate change adaptation, and their implementation rests upon certain <u>fundamental principles</u> against which possible measures should be formulated and judged, namely:

- Investing in the future, not the past
- Working with nature, not against it
- Inclusivity of stakeholders and increasing public awareness
- Building capacity for adaptive management
- Focussing on „no-regrets” and „win-win” measures and solutions
- Change management practices and infrastructure that add to long-term vulnerability.

10 Adaptation to climate variability and change is both a technical and a social process of assessing and responding to present and future impacts, planning to reduce the risk of adverse outcomes, and increasing adaptive capacity and resilience in responding to multiple stresses (EU WFD p.29). Thus, the <u>development of appropriate institutional architecture</u> for adapting to climate change is a very necessary task, and one which other European mountain regions, such as the Alps, have started already[14].

Uncertainty

11 There remains – and will always remain – elements of uncertainty. In practical terms, decisions related to climate change, its impacts and adaptation options cannot be made on simple, single values but need to encompass the range of possible future climate projections. Thus, decision makers will have to handle a bandwidth of values or different scenarios and accept and be explicit about uncertainty. No matter how complex and multi-variable the context is, doing nothing is no longer an option. This, therefore, demands an emphasis on risk management and on measures that build adaptive capacity and flexibility.

Diversity

12 Climate change adaptation is by its nature location-specific, and mountain ecoregions such as the Carpathians contain such great diversity in geography, micro-climate, habitats and species, and culture that inevitably many or most adaptation measures will be developed for a unique location. There is still a role, however, for overarching, transnational, and cross-cutting measures and approaches, since these are necessary to flag, create, and communicate opportunities, funding, best practices, and systematised information flows to ground and community levels.

Part of a Transition to a Climate-proofed Green Economy

13 Countries in the Carpathian region recognise that the global transition to a greener, low-carbon future, has already begun. The European Commission (EC) “urges each Member State to develop national low carbon roadmaps, if not already done”, and is ready to assist countries to develop such a strategic overview climate/energy roadmap or vision. EC has some tools available, and

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[14] For example, see progress and results of the CLISP project: Climate Change Adaptation by Spatial Planning in the Alpine Space, available at www.clisp.eu and the CLIMALPTOUR project: Climate Change and its Impact on Tourism in the Alpine Space at www.climalptour.eu .

will be using the opportunity of the review and planning for the Multi-Annual Financial Framework 2014 - 2020 to see from where funding supports, for example from Cohesion Funds and the Common Agricultural Policy (CAP) can be tapped for financing the longer-term transition.[15] Climate change adaptation should be a fundamental part of this transition, increasingly reflected in National Climate Change Adaptation Plans and National Communications to the UNFCCC process.

14 Countries in the Carpathian region can therefore grasp these opportunities and collectively map out a path towards a climate-proofed future which draws upon, and conserves, the unique natural and cultural values of the Carpathian region, using this as precious capital for a prosperous future in a changing climate.

New Partnerships

15 To succeed, new partnerships will be required. Of course, the involvement not just of government but also civil society, the research and education institutions, and international organisations will be key. So will the involvement of the private sector. If climate change adaptation is integral to the green economy, and the green economy is mostly about jobs, and most jobs are provided by the private sector, then it follows that the private sector is a vital partner in this process. According to UNFCCC the specific expertise of the private sector, its capacity to innovate and produce new technologies for adaptation, and its financial leverage can form an important part in the multi-sectoral partnership that is required for planning and implementation of adaptation[16].

The Issues: Impacts of Climate Change in the Carpathians

Temperature Change

16 Rising winter and summer temperatures threaten local and national policy objectives related to agriculture, winter tourism, rural development and a host of economic and social issues. There will likely be increases in pest incidence and possible spread of invasive and alien species. Some alien species produce allergenic substances which have implications for human health. Higher temperatures can shorten the snow season and raise the snow-line, but lengthen the growing season for agriculture and increase plant productivity (unless it is limited by water availability, see below). Early melting of snows will reduce natural availability of water during summer.

Precipitation Change

17 Most studies indicate an increase in winter precipitation and changes in snow cover. Regional studies point also at periods of lowering precipitation in the summer resulting in lower summer river flows. At the same time, during summer extreme high precipitation over short periods of time are expected. More intensive, short-duration precipitation will lead to increased risk of erosion and risks of land slides. These processes will aggravate the risks of floods and increase the chances of damage caused by floods. These processes will in turn negatively affect water quality. In periods of low precipitation and high temperatures less flow will enhance eutrophication and can trigger toxic algal bloom. Pollutants that originate from point and diffuse sources are less diluted, so concentrations of dangerous and emerging substances will increase. Erosion and landslides will also negatively impact the water quality.

Droughts

18 In general, lower river discharges and drought periods as well as water scarcity events are expected to increase. Groundwater recharge is likely to be reduced, whilst more frequent droughts in summertime will reduce low flows and result in water shortages. In particular, southern parts of Hungary and Romania as well as the Republic of Serbia, are expected to face severe droughts and water shortages. Drier summers will impact chiefly on agriculture and tourism but might also lead to

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[15] European Commission, 2011, A Roadmap for moving to a competitive low carbon economy in 2050, COM2011 (112 Final), p.14., Brussels, Belgium.

[16] UNFCCC, 2010, Adaptation Assessment, Planning and Practice: An Overview from the Nairobi Work Programme on Impacts, Vulnerability, and Adaptation to Climate Change, 84pp., Bonn, Germany.

groundwater depletion and deteriorating water supplies, including the quantity and quality of drinking water available for human consumption and livestock. Indirect, drought will increase the use of groundwater for irrigation and probably also the use for human consumption (especially in summer). Groundwater resources with a high ratio of withdrawals are more vulnerable to these climate change effects.

Floods

19 The floods have affected the livelihoods, threat to the health and lives of people in the Carpathian mountains and foothills. Decreasing snow cover, the unforeseen heavy rains caused by altered climate variability and the related water storage will alter flood regimes and increase risk of flood events, their magnitude, intensity and frequency. In recent years, the number of frequent catastrophic floods has increased, their economic, social and environmental impacts have worsened leading to increased casualties in the region. The floods cause the mud slides, bank erosion, flooding the settlements (especially in lower reaches of rivers). The floods do not respect borders between countries, regions, so there is need for transboundary risk management and adaptation.

Risks to Governmental Policy Objectives

20 National priorities, targets, and goals for development will be impacted by climate change, including governmental objectives on the economy, human health, and the environment. Financially and economically, without adequate and timely adaptation measures, climate change could prove disastrous. The Stern Report estimated that GDP could be reduced by as much as 5% per year, up to 20% by the year 2050[17].

Impacts on Forests

21 Forests will be altered by climate change. Increasing temperatures and higher incidences of drought will lead to shifts in species composition at lower altitudes towards more drought-resistant tree species. More frequent and increased drought stress will increase vulnerability to pest and pathogenic damages, as well as damage from fire. The tree-lines will move upwards, and the northern limit of species will migrate northwards. Some species and communities might collapse as a result of these shifts especially where connectivity and ecological corridors are limited. Particularly vulnerable species include spruce at lower altitudes, beech, maple, oak and lime. Increased soil vulnerability will increase risk of landslides in lower mountain areas. Detailed information on expected impacts on forests is contained in the CARPIVIA report[18], and the IPCC 4th Assessment Report.

Impacts on agriculture

22 Due to changing precipitation, temperature, and seasonality agriculture will experience significant pressures. The precise impacts are likely to be highly focused in specific locations and in some places and for some crops are likely to be positive. In general a shift during spring planting towards winter crops will be possible. Agriculture may also become feasible at higher altitudes, but the effects of elevated CO_2 levels in the atmosphere stimulating plant growth are often threatened by higher temperatures especially in lower altitudes. In some parts of the Carpathians maize and wheat yields will decline, whilst elsewhere sunflower and soya yields might increase due to higher temperatures and migration of these crops' northern limit. Likewise, winter wheat is expected to increase. Unfortunately, vulnerability to pests is predicted to rise, and increasing productivity losses are also expected as a result of soil erosion, groundwater depletion, and extreme weather events. Detailed information on expected impacts on soils and agriculture is contained in the CARPIVIA report, the European Commission's report on climate change and agriculture[19], the CEU/WWF study[20], and the IPCC 4th Assessment Report.

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[17] Stern, 2006, The Stern Review: The Economics of Climate Change – from the executive Summary of the Stern Review, available online at http://webarchive.nationalarchives.gov.uk/+/http:/www.hm-treasury.gov.uk/sternreview_index.htm

[18] Interim Report CARPIVIA Project (2011) Preliminary Assessment vulnerability & potential adaptation measures, 82pp. Available online at http://www.CARPIVIA.eu/about-CARPIVIA/downloads

[19] AEA Energy & Environment, 2007, Adaptation to Climate Change in the Agricultural Sector, Report to European Commission Directorate-General on Agriculture and Rural Development, Report no. AGRI-2006-G4-05, by AEA Energy & Environment and Universidad de Politecnica de Madrid, 245pp., Madrid, Spain.

Impacts on water

23 Both water quantity and quality, in addition to seasonally, will be affected by climate change. Overall, a decline in total annual run-off is predicted for southern and eastern parts of the Danube basin, while western and northern parts might experience increases. The changes in annual run-off in the mountain part of the Dniester basin will not be as severe as in the Lower Dniester, however the changes will be visible seasonally through the increase of the run-off during winter period. Water temperature in streams, rivers and lakes will increase. Because of temperature increase, the modernization and/or development of irrigation system in downstream areas will be needed, that could be complicated in the situation of water deficit. The possible impacts on the quantity and quality of drinking water maybe important in the region as well. Detailed information on expected impacts on water and water management is contained in the CARPIVIA report, the ICPDR Danube Adaptation Study[3], the CEU/WWF study, UNECE Dniester project and the IPCC 4th Assessment Report.

Impacts on Grasslands

24 Grasslands are very important in the Carpathians and could said to be emblematic of the ecoregion. Temperature increases, more extreme droughts and floods, soil erosion, an upward shifting tree line and increased vulnerability to invasive species are all expected to reduce grassland quality and coverage, leading to habitat fragmentation and loss of species. Whilst for the time being arable agricultural intensification and abandonment of traditional grazing practices are a more immediate threat, the longer-term impacts of climate change are expected to be severe. Detailed information on expected impacts on grasslands is contained in the CARPIVIA report, the CEU/WWF study, and the IPCC 4th Assessment Report.

Impacts on Biodiversity

25 Landscapes, habitats, flora and fauna show characteristics and unique features occurring only in the Carpathians. Endemic, alpine, relict habitats and species are the result of long-term evolution, migration and adaptation processes, which started long before human influences came into the area. Carpathian ecosystems also represent specific animal characteristics, with endemic species that face extinction in other mountain areas in Europe. Specific bird species are also in relatively good population numbers protected. The changes of temperature and precipitation regimes will affect the physiological processes of fauna and flora, and can cause the displacement of natural boundaries and the loss of natural ecosystem, including the “corridors” for the migration of rare and endemic species. Because of the increasing of temperature, the migration of pests, fungus and acarus, as well as atypical species will increase; this can cause the replacement of valuable species by low value species. Detailed information on expected impacts on biodiversity is contained in the IPCC 4th Assessment Report (Chapter 1 - 1.3.5 Terrestrial biological systems).

Impacts on Wetlands

26 High altitude wetlands are crucial for both flood management (acting as sponges and thus levelling off flood peaks in winter and low flows in summer) and for biodiversity. Increased air temperatures will lead to drying out of wetland soils through increased evapotranspiration, compounded by higher incidence of drought. Further wetland loss would reduce habitats for the many dependent plant and animal species, and lead to habitat fragmentation which could threaten migratory birds and amphibians at a regional scale. Detailed information on expected impacts on wetlands is contained in the CARPIVIA report, the ICPDR Danube Adaptation Study, the CEU/WWF study, and the IPCC 4th Assessment Report.

Impacts on Tourism

27 Tourism will experience both positive and negative pressures from climate change. Shorter and milder winters will impact upon snowfall levels meaning that basic conditions for ski-based and other winter sports tourism are less favourable than currently. On the other hand, rising temperatures in summertime elsewhere, for example the Mediterranean, might drive more tourists to the mountains

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[20] CEU, 2008, Impacts of and Adaptation to Climate Change in the Danube-Carpathian Region, Overview study commissioned by the WWF Danube-Carpathian Programme, September 2008, 56pp., Budapest, Hungary.

for relatively more comfortable summer vacations. Summer seasons might become longer, winter seasons shorter. Detailed information on expected impacts on tourism is contained in the CARPIVIA report, the CLIMALPTOUR report (focussing on the Alps), the CEU/WWF study, and the IPCC 4th Assessment Report.

Priorities for the Signatories:

Policy Responses to create a Path to a Climate-Proofed Carpathian Economy

28 Whilst much practical adaptation is done at the farm, business, or household level, policies and funding frameworks can boost or hinder the capacity for adaptation, and as noted by IPCC (2007) there is an important role for public policy in facilitating adaptation to climate change. This includes reducing vulnerability and increasing adaptive capacity of people and infrastructure, providing information on risks for private and public investments and decision-making, and protecting public goods such as habitats, species and culturally important resources.[21]

29 Mainstreaming of climate change adaptation objectives into policy and funding framework is a first step, in order to prevent precious investment being wasted as a result of changing (climatic) baseline conditions when initiatives come on stream. Key economic sectors such as water, agriculture, transport, and health require planning against a range of available climate change scenarios in order to test which plans and measures will continue to make technical and financial sense, and thus, to decide upon low-risk and no-regret actions. According to IPCC, there is scope for mainstreaming at both national and international levels. The Carpathian Convention process is seen as potentially an ideal vehicle for providing leadership and coordination for developing a united, comprehensive, regional approach to adaptation activities[22].

30 The Carpathian Convention's emphasis on ecosystem management and recognition of the importance of ecological integrity lends itself naturally to a focus on ecosystem-based adaptive approaches to climate change adaptation in the region. As noted by the European Commission, focusing especially on the resilience of healthy aquatic and water bound ecosystems to changing and degrading conditions provide a cost-effective and relatively easy way to achieve adaptation[23]. Increased transnational cooperation for example in the joint spatial planning, designation, and management of expanded protected areas to act as refuges for habitats and species also focusing on habitat connectivity would therefore make both ecological and economic sense for the countries in the region as well as contribute to climate change adaptation.

31 The added value of increased transnational cooperation and joint activities is especially strong in terms of planning for climate change adaptation. So much of the predicted impacts of climate change relate to seasonal and geographical shifts. This is true for species and communities (forests, tree-lines, northern limits) as well as for socio-economic aspects (tourist arrivals, tourism seasons). Many of the possible measures are thus best planned using a geographical scale of the ecoregion, rather than the nation-state. Further, many of the tools and capacities required for climate change adaptation which are currently missing, such as the capacity for designation and mapping of future refuge habitats for wetlands and grasslands, synthesised and comparable climatological data, and firm strategies for adaptation on a sector-by-sector basis, are either only possible at the transnational level, or are equally missing in each country, meaning that joint initiatives with external funding could fill these gaps and build cooperative capacity at the same time.

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[21] IPCC, 2007, 4th Assessment Report, Working Group II, Impacts, Adaptation and Vulnerability Section 17.4.1., IPCC, Geneva, Switzerland and New York, USA.

[22] CEU, 2008, Impacts of and Adaptation to Climate Change in the Danube-Carpathian Region, Overview study commissioned by the WWF Danube-Carpathian Programme, September 2008, p.36., Budapest, Hungary.

[23] EU Guidance Document Number 24 – River Basin Management in a Changing Climate, technical report – 2009 – 040, Common Implementation Strategy for the Water Framework Directive (2000/60/EC), p.40, Brussels, Belgium.

32 In addition, the priority areas of the Carpathian Convention process, as defined by the current Working Groups and the overall Strategic Action Plan for the Carpathian Area[24], now require climate change considerations to be built into future activities of the Working Groups of the Carpathian Convention, workplans and decision-making. This is also true of the EU Strategy for the Danube Region (EUSDR[25]) which is highly relevant for the Carpathian Space especially in terms of policy synergies and funding priorities and opportunities. Indeed, the Strategy's Action Plan foresees cooperation and project-based activities of the Strategy's implementation as an opportunity to put in place the required elements on which to build a Danube Adaptation Strategy (finalised in December 2012) in the nearest possible future[26].

Institutional and organisational responses

33 Examination of the Alpine experience suggests that a designated pan-Convention policy-, funding-, coordination and communication context for climate change adaptation would be very valuable. Hence the designation of a Carpathian Space is recommended. The uniqueness and diversity of the Carpathians, together with the fact that when seen in isolation in each national context, they are normally a relatively small proportion of any given country, lend themselves to joint actions. Many measures, especially „preventative” and „preparatory” ones relating to information gaps, research, and monitoring together with broad capacity-building and awareness-raising, make sense if carried out a broad ecoregional scale. Policies and funding frameworks which reflect this geography would therefore be very useful.

34 Adaptive management[27] requires a good information base and constant updating and review of data. This is especially true of climate change adaptation, which rests first on thorough analysis of the baseline and time-series data in order to set context for future projections and scenarios. The Carpathians are lacking need a systematised, easily comparable set of climatological and climate impact related datasets between countries. A common and accessible information system is created by CHM and the aspects regarding climate changes must to be taking in consideration in this system already in place. .

35 Following on from that, a thorough research and literature analysis on climatological datasets, information, articles and scientific knowledge on climate change impacts and adaptation in the Carpathians is required, including – crucially – sources of information published or unpublished in local languages, since most relevant data for the Carpathians is in national languages. With this foundation, a logical monitoring system can be established, with various models and examples available as a guide. More information on information, baselines, and monitoring is provided in the IPCC 4th Assessment Report, and the Nairobi Work Programme, an agenda item under the United Nations Framework Convention on Climate Change (UNFCCC).

36 The EU Water Framework Directive (WFD) requires participatory river basin management planning, and although climate change is not explicitly included in its text, the step-wise and cyclical approach of the river basin management planning process makes it well suited to adaptively manage climate change impacts[28]. All Carpathian countries, if appropriate[29], are implementing this Directive

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[24] UNEP, undated, Strategic Action Plan for the Carpathian Area, 21pp., agreed at COP3, Bratislava, Slovakia.

[25] See http://www.danube-region.eu/pages/what-is-the-eusdr

[26] European Commission Staff Working Document, 2010, Action Plan: Accompanying document to the Communication from the Commission on the European Union Strategy for the Danube Region, p.40., SEC (2010) 1489, Brussels, Belgium.

[27] EU WFD Guidance p.4: According to the Intergovernmental Panel on Climate Change (IPCC), adaptive capacity may be defined as the ability to cope, adapt or recover from the effects of a hazard (in this case, climate change). Examples of steps that can be taken to build adaptive capacity include: increasing knowledge of potential climate risks for individual river basins; strengthening data collection and knowledge exchange amongst key stakeholders; cross-sectoral integration and partnership working; awareness raising education and training.

[28] EU Guidance Document Number 24 – River Basin Management in a Changing Climate, technical report – 2009 – 040, Common Implementation Strategy for the Water Framework Directive (2000/60/EC), p.2, Brussels, Belgium.

[29] Non EU Member States as far as they are part of the Carpathian Region they implement the Directives in the framework of the relevant decisions adopted within the Danube River Convention.

and relevant, associated approaches including the Directive on Floods and the EU Water Scarcity and Droughts Strategy to mitigate or prevent consequences of climate change The Second Cycle of river basin management planning, for implementation over the period 2015-2021, is required to take into account adaptation requirements. Thus, opportunities exist to avoid duplication of adaptation measures between the Carpathian and Danube processes and to integrate Carpathian objectives into the Danube river basin management planning and into the Danube Climate Change Adaptation Strategy, currently finalized and for which analysis have already been undertaken[30].

37 At the international level, there further a strong need for liaison with river basin management planning bodies for the other major rivers draining from the Carpathians, namely the, Dniester, Tisza and Vistula..

38 Financial resources are limited. A key action is to create flexible and equitable financial instruments that facilitate benefit - and burden-sharing, social learning and that support a diverse set of potentially better-adapted new activities rather than compensate for climate impacts on existing activities. The perception of fair sharing of costs and benefits between actors is central to the successful implementation of adaptation and has to be addressed in adaptation planning. In the region, European and/or national government financial support is often sought for to implement adaptation. However, mainstreaming adaptation can complicate existing relations with donors or subsidies. The European agro-environmental schemes for instance are not designed for inter-annual land use change depending on water availability. Thus, the effectiveness of European funding schemes has to be re-evaluated in supporting adaptation. Creating markets for adaptation is another key challenge (e.g. encouraging cities and industries to buy in on upstream flood water storage and floodplain management). Opportunities exist for public-private partnerships in which marketable products obtain additional public support in exchange for providing social and environmental services that support adaptation. This action supports economic incentives including pricing and taxation of water resources, micro-grants (e.g. to diversify production systems especially in low altitude ski-resorts), payments for ecosystem services, and water allocation schemes.

Cross-Cutting Opportunities

39 There are many cross-cutting opportunities for mainstreaming climate change adaptation efforts into the relevant sectors. These include climate-cross compliance, and strategic environmental assessment. At relatively little or even zero cost, governments can boost adaptation policy, practice, and capacity by instigating such cross-cutting measures. Additional (human) capacity in the form of awareness, skills, and training are required. Recommendations for tentative actions of this type are given below in the section “Actions”, and in the accompanying Matrix of Measures (Annex: Matrix of Potential Climate Change Adaptation Measures in the Carpathians, which lists possible adaptation measures, policy linkages, actors involved, and forthcoming funding opportunities with timelines of decision-making).

40 Climate-Cross Compliance is an area of particular promise for climate change adaptation. For several years now agriculture and rural development funding (payments, subsidies, grants) has been contingent upon compliance with EU environmental standards, meaning that in order to be eligible for a particular support, a farm has to demonstrate it is complying with various EU environmental objectives, laws, standards. The same principle[31] can be applied to climate change adaptation, meaning that all EU and national funding (not just agriculture) can be made contingent upon

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[30] ICPDR has to date conducted a detailed study on climate change and is now putting together a basin-wide strategy, for more details see http://www.icpdr.org/icpdr-pages/climate_adaptation_study.htm

[31] A working definition of cross-compliance in its more usual use, accessed from the European Commission Agriculture and Rural Development webpages: http://ec.europa.eu/agriculture/envir/cross-compliance/index_en.htm as follows: “Cross-compliance is a mechanism that links direct payments to compliance by farmers with basic standards concerning the environment, food safety, animal and plant health and animal welfare, as well as the requirement of maintaining land in good agricultural and environmental condition. Since 2005, all farmers receiving direct payments are subject to compulsory cross-compliance.” (Accessed 18 May 2012).

demonstrated consideration and adaptation to climate change variations. This would very rapidly mainstream adaptation measures into many sectors including agriculture, transport, small and medium sized enterprise development, and public sector procurement.

41 Strategic Environmental Assessment (SEA), either alone or as part of a sustainability appraisal, can help to ensure that plans and programmes take full account of climate change issues. The SEA Directive (2001/42/EC) requires identification and evaluation of planned impacts on a number of environmental issues, including climatic factors; and, where appropriate, to put measures in place to minimise and respond to significant impacts identified. Greater use of, and adherence to, SEA processes would therefore "climate-proof" all sectoral plans and investments.

Project and programme oriented responses:

Opportunity for the EU Funds from 2014-2020: Steer the Region's Development Towards a Climate-Proofed Carpathian Space

42 The path to a green economy and climate-proofing can be smoothed by participation in EU processes and through accessing EU and national funding sources which are increasingly supportive. The one trillion euro budget for 2014-2020 is currently being discussed, and in order to secure a climate-proofed, low carbon future for Europe, will need to focus on two complementary priorities[32]:

- Making intelligent investments in green economic sectors that will be the lead markets of the future including renewable energies, energy savings, sustainable agriculture, and biodiversity management.
- Smarter spending through phasing out of subsidies that are environmentally harmful and economically ineffective. This would maximize win-win opportunities delivering benefits for the environment, jobs and the economy.

43 These investments need to be focussed also on stimulating climate change adaptation. The Carpathian space can be a leading example of ecosystem-based adaptation measures which are beneficial for both people and the environment, whilst at the same time maximising the resilience of the ecoregion to current and future climatic variations. Linking to existing policies and funding opportunities is therefore vital, as is shaping new funding architecture through joint definition of goals, measures, and coordinated actions. This latter will include the development of a new EU Biodiversity Strategy which halts further habitat loss and restores ecosystem services, and is part of the Europe 2020 Strategy[33], together with the EU Roadmap on a Resource Efficient Europe, and the EU Adaptation Strategy. The other financial mechanisms, e.g. European Neighborhood and Partnership Instrument (ENPI) can also be involved for the adequate implementation of the climate change adaptation actions on the whole territory of the Carpathian Space.

44 Recommendations for tentative actions of this type are given below in the section "Actions", and in the accompanying Matrix of Measures (Annex: Matrix of Potential Climate Change Adaptation Measures and Actions in the Carpathians, which lists possible adaptation measures, policy linkages, actors involved, and forthcoming funding opportunities with timelines of decision-making).

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[32] WWF, 2011, WWF priority demands to the Danish Presidency 1 January – 30 June 2012, WWF Position Paper, 12pp., December 2011, Brussels, Belgium.

[33] European Commission, 2011, Communication COM(2011) 21 A resource-efficient Europe – Flagship initiative under the Europe 2020 Strategy, p.6., 17pp., 26.1.2011, Brussels, Belgium. Also available online at http://ec.europa.eu/resource-efficient-Europe/pdf/resource_efficient_europe_en.pdf

Potential Priority Climate Change Adaptation Actions

45 The Carpathian Convention responds to the challenge resulting from climate change by developing this strategic agenda. The following actions are recommended for prioritised implementation and represent initiatives which would act as a practical and inspiring demonstration of adaptation in this region, and at the same time help build vital capacity for further actions. Likely to attract external funding, they are proposed for the Carpathian Convention to discuss and consider for implementation and to build momentum towards the development of a Carpathian Climate Change Adaptation Strategy.

Capacity Building Programme which Draws on, and Enhances, the Connectivity of the Region
Awareness-raising, training, and information exchange programme on climate change adaptation for local authorities, line ministries, and NGOs in the Carpathian region. Will enhance understanding of climate change in the Carpathians, opportunities for ecosystem-based adaptation, funding opportunities, and transnational planning.

Information management and Awareness Raising
Programme of technical assistance, training, and data management hard- and software for local authorities, line ministries, and NGOs, together with stakeholders from the scientific and research community, on climate change data, scenarios, information management risk assessment and mapping to increase analytical and decision-making capacities for climate change adaptation. This could feature an “IPCC-style” process for pulling together scientists and knowledge in the region.

Climate-Proofing of Infrastructure, Investments and Climate-Cross Compliance
Infrastructure improvement, including the re-evaluation of existing (water) infrastructure in the light of its contribution to vulnerability to climate change (e.g. the contribution of river regulation to high and low river flow levels). Assess and promote the location specific contribution of ecosystem-based approaches to climate-proof sustainable development.

Workshop series for line ministries of Agriculture, Economy, Spatial Planning, Environment, Energy and Transport, together with local authorities and NGOs, on mainstreaming climate change adaptation into national and regional policy frameworks, including EU funding possibilities both now and in the new, post-2014, budgetary timescale. Example: definition of policy needs to make agriculture and rural development support contingent upon incorporation of climate change adaptation measures into farm business plans, rural development plans, etc. (from CAP, LEADER, agri-environment, direct payments, subsidies and grants). This action could result in guidelines for climate proofing assessments.

Development of Forestry Measures for Climate Change Adaptation
Joint development of specific forestry measures (see accompanying Matrix) by the Carpathian Convention Sustainable Forest Management Working Group (Forest WG), the Carpathian Convention Working Group on Conservation and Sustainable Use of Biological and Landscape Diversity (Biodiversity WG) and the Climate Change WG in a trans-national context, to focus on mapping and designation, identification of refuges, cross-border linkages, and management measures such as thinning, fire management, and invasive species management which enhance ecological integrity and climate change adaptation capacity of managed and natural forest ecosystems. In particular, the preparation of 'what if' plans to be implemented after an extreme event, e.g. preparation of a management strategy to be implemented upon significant forest loss after an extreme weather event or logging. In the vicinity of villages in particular direct activities to reduce the impact of (illegal) logging on landslides, erosion and flash floods.

Making Biodiversity Management More Dynamic
Joint development of specific conservation and protected areas measures (see Matrix) by the Biodiversity WG, the Forest WG, and the Climate Change WG in a trans-national context, to focus on mapping and designation, identification of refuges for wetlands and grasslands,

adaptive management best practices, cross-border linkages, and ecological integrity for climate change adaptation. Consider the directing (all) activities to near-nature areas and natural retention areas. Recognising the growing importance of non-native species in ecosystem management.

Evaluation of Carpathian Ecosystem Services
The linkage between water, wetlands and forests exemplify the importance of managing ecosystems as a whole to protect their ecological character, their freshwater resources and related ecological services that are vital for human life. The Carpathian Ecosystems provide a wealth of services which in financial terms represent a huge value. In accordance with the Millennium Ecosystem Assessment the services provided can be subdivided into provisioning services (agricultural products, forest products), regulating services (water retention and storage, erosion prevention, climate regulation) cultural (including recreational and tourism) and supporting (soil formation, nutrient cycling). Healthy ecosystems are more capable of delivering these services than deteriorating ecosystems. Investing in the protection, management and restoration of ecosystems supports the delivery of these valuable services. Valuing the services the Carpathian ecosystems deliver is a necessary step towards clarifying the need for the protection and management of the Carpathian ecosystems and their contribution to mitigate and adapt to climate change impacts. Valuing ecosystem services can help to design and implement actions to correct market failures that are harmful to the affected ecosystems and the economy.

Capacity-Building on Proposal-Writing for Adaptation Funding
Establishment of a small, multi-disciplinary, international team or network which works with local authorities and NGOs and delivers technical assistance on sourcing funds for climate change adaptation measures.

Working Group on Climate Change
Continue the work of the Working Group on Climate Change with the mandate of the Contracting Parties to advice the Secretariat and the Contracting Parties on policies, actions, research, data gathering and projects relevant for mitigating and adapting to climate change impacts in the Carpathians. The WG has the overview of relevant projects and policies relevant for climate change in the Carpathians and bears the responsibility to coordinate climate change adaptation policies and projects in the Carpathians with other relevant government and non-government organisations.

More potential actions are listed in the accompanying Matrix.
ENDS

List of acronyms and abbreviations

Biodiversity WG	**Carpathian Convention Working Group on Conservation and Sustainable Use of Biological and Landscape Diversity**
CAP	Common Agricultural Policy
CarpathCC	Climate Change in the Carpathian Regio
CARPIVIA	Carpathian Integrated Assessment of Vulnerability to Climate Change and Ecosystem – Based Adaptation Measures
CEU/WWF	*Central European University/ World Wide Fund for Nature*
CHM	*Clearing House Mechanism*
CLIMALPTOUR project	Climate Change and its Impact on Tourism in the Alpine Space
Climate Change WG	Working Group on Adaptation to Climate Change
CLISP project	Climate Change Adaptation by Spatial Planning in the Alpine Space
COP 4	Fourth Meeting of the Conference of the Parties to the Carpathian Convention
COP3	Third Meeting of the Conference of the Parties to the Carpathian Convention
DG ENV	Directorate General for Environment (European Commission)
EC	European Commission
ENPI	European Neighborhood and Partnership Instrument
EU	European Union
EU WFD	*European Union Water Framework Directive*
EUSDR	EU Strategy for the Danube Region
Forest WG	Carpathian Convention Sustainable Forest Management Working Group
GDP	Gross domestic product
ICPDR	International Commission for the Protection of the Danube River
IPCC	Intergovernmental Panel on Climate Change
SEA	Strategic Environmental Assessment
UNECE	*United Nations Economic Commission for Europe*
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
WG	Working Group

10 Metadata catalogue and information system

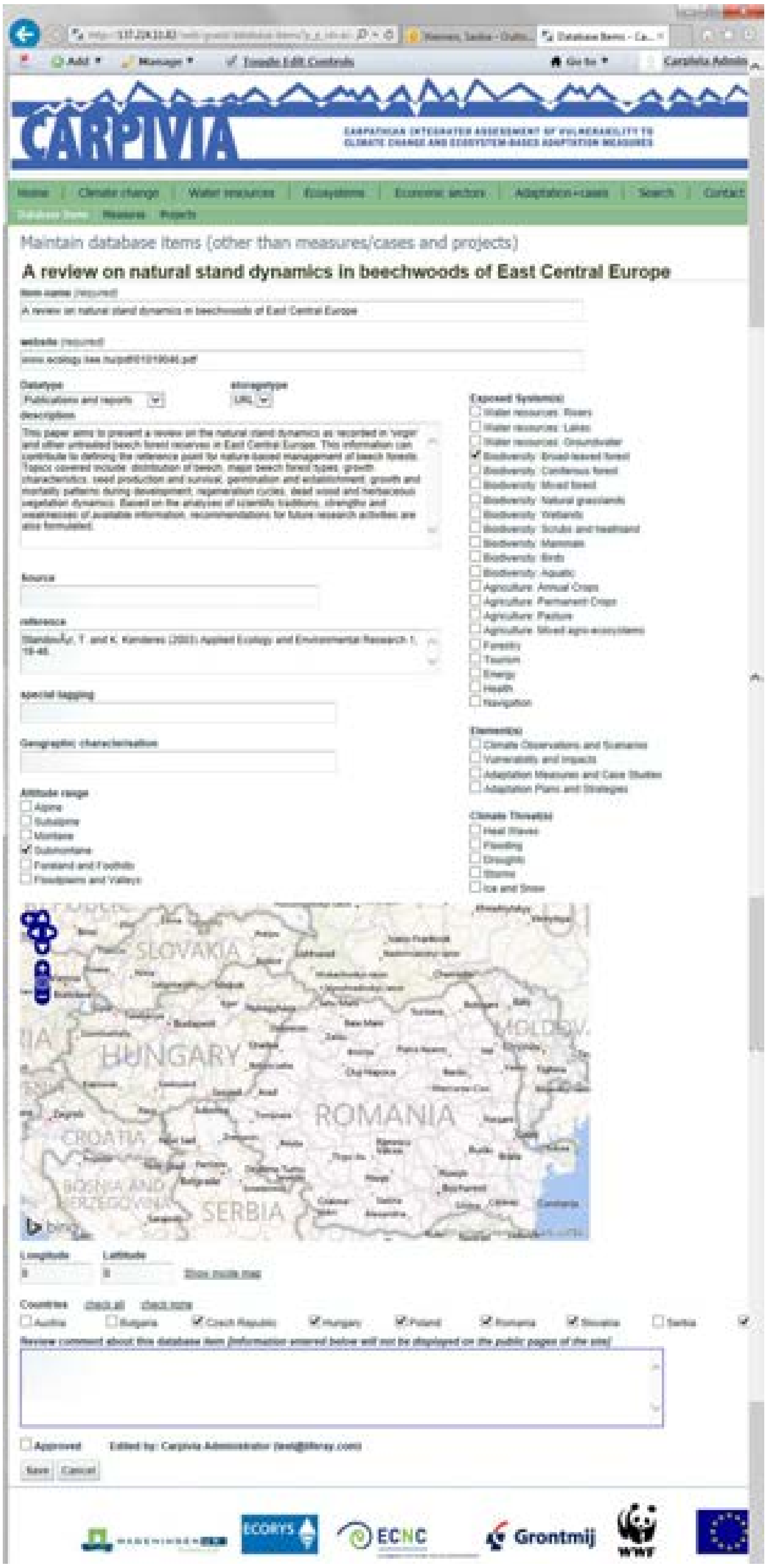
One of the requirements of the ToR of the CARPIVIA Projects was that the data and results of the entire project would be made available in metadata catalogues on vulnerability and adaptation. The metadata catalogues were to be made publicly available through a dedicated website, created for the project in close cooperation with and for inclusion in the EU Adaptation Clearinghouse [*now Climate-ADAPT*]. All metadata catalogues created are to be compliant with the metadata regulation formats of the European Commission Regulation (EC) No 1205/2008. Furthermore the metadata catalogue should follow the relevant to the project topic categories in accordance with ISO 19115.

As Alterra coordinated the development of the European Climate Adaptation website Climate-ADAPT it was decided to create a platform analogue to Climate-ADAPT, focussing on the Carpathian region. This would also warrant that the Metadata complies ISO 19115 and Core INSPIRE. The meta-database and supporting Internet site have been developed using the same technology as the Climate-ADAPT website and underlying database. Data is stored in the database in a format that is compatible with Climate-ADAPT (Version 2012. In 2013 a number of database fields have been changed or added in Climate-ADAPT, yet most fields would still agree 1-1). For the classification of ecosystems we combined the CORINE land use classification and the classification used in Climate-ADAPT. Thus the database offers the user some extra classes to characterize the ecosystem and ecosystem based production systems at hand, whereas at the same time these classes can easily be collapsed to fit with the Climate-ADAPT database (see also examples in Figure 10-1).

Current / temporary address: 137.224.11.82
(also accessible through CARPIVIA.eu site -> vulnerability explorer)
You can view the website and database items without logging in.
Example of database item: http://137.224.11.82/web/guest/viewitem?item_id=38

The created website provides a catalogue services for reviewing data (catalogue viewers) and services for store of metadata specific for the instance of the Carpathian region. To maintain / review / add database items you can 'sign in' (click in right upper corner). A username and password can be provided by emailing the contacts on the webpage (Saskia Werners (saskia.werners@wur.nl)).

Figure 10-1 illustrated the fields that can be entered for the main three database items.



Maintain database items (other than measures/cases and projects)

A review on natural stand dynamics in beechwoods of East Central Europe

item name (required)
A review on natural stand dynamics in beechwoods of East Central Europe

website (required)
www.ecology.kee.hu/pdf/0101019046.pdf

Datatype: Publications and reports

storagetype: URL

description
This paper aims to present a review on the natural stand dynamics as recorded in 'virgin' and other untreated beech forest reserves in East Central Europe. This information can contribute to defining the reference point for nature-based management of beech forests. Topics covered include: distribution of beech, major beech forest types, growth characteristics, seed production and survival, germination and establishment, growth and mortality patterns during development, regeneration cycles, dead wood and herbaceous vegetation dynamics. Based on the analyses of scientific traditions, strengths and weaknesses of available information, recommendations for future research activities are also formulated.

Source

reference
StandovÃ¡r, T. and K. Kenderes (2003) Applied Ecology and Environmental Research 1, 19-46.

special tagging

Geographic characterisation

Altitude range
☐ Alpine
☐ Subalpine
☐ Montane
☑ Submontane
☐ Foreland and Foothills
☐ Floodplains and Valleys

Exposed System(s)
☐ Water resources: Rivers
☐ Water resources: Lakes
☐ Water resources: Groundwater
☑ Biodiversity: Broad-leaved forest
☐ Biodiversity: Coniferous forest
☐ Biodiversity: Mixed forest
☐ Biodiversity: Natural grasslands
☐ Biodiversity: Wetlands
☐ Biodiversity: Scrubs and heathland
☐ Biodiversity: Mammals
☐ Biodiversity: Birds
☐ Biodiversity: Aquatic
☐ Agriculture: Annual Crops
☐ Agriculture: Permanent Crops
☐ Agriculture: Pasture
☐ Agriculture: Mixed agro-ecosystems
☐ Forestry
☐ Tourism
☐ Energy
☐ Health
☐ Navigation

Element(s)
☐ Climate Observations and Scenarios
☐ Vulnerability and Impacts
☐ Adaptation Measures and Case Studies
☐ Adaptation Plans and Strategies

Climate Threat(s)
☐ Heat Waves
☐ Flooding
☐ Droughts
☐ Storms
☐ Ice and Snow

Longitude: 0 **Latitude**: 0

Countries
☐ Austria ☐ Bulgaria ☑ Czech Republic ☑ Hungary ☑ Poland ☑ Romania ☑ Slovakia ☐ Serbia ☑

Review comment about this database item (information entered below will not be displayed on the public pages of the site)

☐ Approved Edited by: Carpivia Administrator (test@liferay.com)

a) Database items: documents


b) c)

Figure 10-1 *Illustration of three main meta-database items a) documents, b) measures / cases, c) projects.*

10.1 Strategies for the uptake of the meta-database

Three strategies for the uptake of the meta-database and supporting website have been discussed with the EEA and other parties. The EEA is a key partner because of the hosting and maintenance of Climate-ADAPT:

1. Include the direct CARPIVIA project deliverables.
2. Select which of the > 100 Carpathian database items are relevant for Climate-ADAPT and enter these. Starting point of the selection is the ‘CLIMATE-ADAPT maintenance training manual -

version 1 8 (03 05 2013)' and the criteria for database items in Climate-ADAPT. This results in the following preliminary considerations on database items:

- reports, portals and research projects can in principle be included;
- no/very limited inclusion of general adaptation options (since these are already extensively included in Climate-ADAPT);
- no maps to be included (since Climate-ADAPT covers only European wide maps for the moment);
- selected case studies to be included. As few case studies exist from the Carpathian region these database items are particularly valuable.

Entered database items would next go though regular Climate-ADAPT review.

3. Include mountain page and/or Carpathian page (as for the Baltic sea region, see: http://climate-adapt.eea.europa.eu/transnational-regions/baltic-sea/generalhttp://climate-adapt.eea.europa.eu/transnational-regions/baltic-sea/general). This option needs further discussion between EEA and Carpathian convention (and other mountain regions). It requires largest resources from involved parties (EEA, Carpathian convention (supported by European Academy of Bolzano (EURAC)), Science for the Carpathians (S4C), Alterra).

Alterra carries out Strategy 1 + the pre-selection for Strategy 2 within the CARPIVIA project. Strategy 3 requires more coordination and could be implemented progressively depending on ongoing discussion between the EEA and the Carpathian Convention. These discussion include hosting and maintenance of database items & possibly the transfer of full transfer of the supporting website from CARPIVIA to host.

10.2 Current status website & meta-database items

At present the database contains 118 items
►Publications and reports (91)
►Information portals (3)
►Research and knowledge projects (5)
►Adaptation options (8)
►Case studies (10)
►Organisations and people (1)

In addition the supporting website contains dedicated pages on vulnerability and adaptation options for/in the selected ecosystems and ecosystem based production systems. The structure of the website closely matches the CARPIVIA interim and final report.

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Annexes

Annex A: Long List Adaptation measures

		Measure relevant for:					Selection criterion 1: climate change threat				Selection criterion 2							
													Non-structural measures					
General measure (new)	Specific measure (long list)	Forest	Water	Agriculture	Grassland	Wetlands	drought	flood	deterioration biodiversity	heat waves	grey	green	management / practices	risk prevention	Economic, financial	regulatory	landuse change, allocation	awareness, information
Increase species and genetic diversity	Practice intensive management to secure populations	x	x		x	x			x				x					
	Translocate species	x	x		x	x			x								x	
	Broaden genetic and species diversity in restoration and forestry	x	x		x	x			x			x						
	Do not implement CO2 emission mitigation projects that negatively impact biodiversity								x							x		
	Establish neo-native forests plant species where they were in the past, but are not found currently	x							x			x					x	
	Experiment with refugia	x	x		x	x	x	x	x	x								
	Focus on annual plants rather than perennials near climate boundaries	x			x	x			x			x						
	Manage for landscape asynchrony	x			x	x			x								x	
	Manage populations to reduce temporal fluctuations in population sizes	x	x		x	x			x		x	x	x					
	Protect functional groups and keystone species	x	x		x	x			x			x	x			x		
Increase connectivity	Create ecological reserve networks, large reserves which are interconnected by small reserves (stepping stones)	x	x						x			x					x	
Protected areas	Increase number of reserves	x	x		x	x			x									
	Increase size of reserves	x	x		x	x			x							x		
	Protect many small reserves rather than single	x	x		x	x			x							x		
	Create buffer zones around reserves	x	x		x	x			x			x						
	Protect refugia current and predicted future	x	x		x	x			x									
	Represent each species in more than one reserve	x	x		x	x			x									
	Locate reserves in areas of high heterogeneity, endemism	x	x		x	x			x									
	Maintain natural disturbance dynamics of ecosystems	x	x		x	x	x	x	x	x								
	Secure boundaries of existing preserves	x	x		x	x			x									
	Locate reserves at northern boundary of species' ranges	x	x		x	x			x									
	Adjust park boundaries to capture anticipated movement of critical habitats	x	x		x	x			x			x						
	Create linear reserves oriented longitudinally	x	x		x	x			x			x						
	Focus protection on sensitive biomes	x	x		x	x			x									
	Increase wetland protection					x	x		x	x								
	Locate reserves so major vegetation transitions are in core	x			x	x			x			x						
	Locate reserves at core of ranges	x	x		x	x			x									
	Protect primary forests	x							x				x			x		
	Protect urban green space				x								x			x		
	Protection of wetland/floodplain/river/upland watersheds		x			x			x				x			x		
	Conserve, protect and restore vegetation and forests especially in mountainous regions	x											x					
Adaptive management (policy)	Integrate CC into planning exercises (reserve, pest outbreaks, harvest schedules, grazing limits, incentive programmes)			x			x	x		x			x			x		x
	Adopt long-term and regional perspective in planning, modelling and management						x	x		x			x					
	Develop adaptation programmes now, early adaptation is encouraged	x	x	x	x	x	x	x	x	x			x	x				x
	Create culturally appropriate adapation/management options	x	x	x	x	x							x					
	Develop best management practices for CC scenarios	x	x	x	x	x	x	x		x			x					
	Practice proactive management of habitat to mitigate warming	x	x		x	x	x	x		x			x					
	Start strategic zoning of landuse to minimize climate related impacts												x				x	
	Use triage in short-term to prioritize action												x					

Annex B: Meetings in which CARPIVIA results were shared and discussed

When	Where	Meeting
22-24 March '11	Budapest	Water conference (related to SCENES project)
27-30 March '11	Budapest	ClimWatAdapt, MEDIATION, CLEARINGHOUSE coordination meeting
31 March-1April	Vienna	Meetings with ICPDR, Carpathian Convention, S4C
12-13 April 2011	Uzhgorod, Ukraine	ICPDR Tisza Group organizes its 16th meeting and final stakeholder meeting of UNDP/GEF Tisza project
12-14 April 2011	Geneva	Workshop “Water and Adaptation to Climate Change”, UNECE
26-27 May 2011	Bratislava, Slovak Republic	COP3 Meeting of the Carpathian Convention (organised by UNEP-Interim Secretariat for the Convention and Slovak Government)
26 May 2011	Bratislava	The Science for the Carpathians (S4C) Meeting
10-12 September 2011	Munich	Danube climate change study for ICPDR (University of Munich, Prof. Mauser)
6 Febr 2012	Brussels	Adaptation Steering Group and development Climate-Adapt
29 May 2012	München	ICPDR meeting on adaptation strategy
30 May – 2 June 2012	Stará Lesná	Workshop at Forum Carpaticum 2012 co-hosted with Carpathian Convention Secretariat
23 - 24 October 2012	Eger	Workshop and Working Group meeting with Carpathian Convention, CarpathCC, and Carpatclim
10-14 March 2014	Vienna	Carpathian Convention working group on adaptation + expert meeting.
Project duration	*various*	Back to back with the meetings listed above project meetings were held for coordination with Carpath-CC. In addition a coordination meeting was held in Budapest and one in Brussels
Planned		
September 2014	Lviv	Workshop at Forum Carpaticum 2012 co-hosted with Carpathian Convention Secretariat
September 2014	Mikulov	COP4 Meeting of the Carpathian Convention

Annex C: Members steering committee

Name	Email	Affiliation (at start of project)
Jacques Delsalle	Jacques.Delsalle@ec.europa.eu	DG Env, Unit D.1. Water
Günter Raad	Guenter.Raad@ec.europa.eu	DG Env, unit impact assessment
Angelo Innamorati	Angelo.Innamorati@ec.europa.eu	DG Agri
Natalie Verschelde	Natalie.Verschelde@ec.europa.eu	DG Regio
Myriam Driessen	Myriam.Driessen@ec.europa.eu	DG Agri
Evdokia Achilleos	Evdokia.ACHILLEOS@ec.europa.eu	DG Env
Szilvia Bosze	Szilvia.BOSZE@ec.europa.eu	DG Env
Paulo Barbosa	paulo.barbosa@jrc.ec.europa.eu	JRC
Jürgen Vogt	juergen.vogt@jrc.ec.europa.eu	JRC
Harald Egerer	harald.egerer@unvienna.org	Interim Secretariat of the Carpathian Convention
Sonja Koeppel	Sonja.Koeppel@unece.org	UNECE
Raimund Mair	Raimund.MAIR@unvienna.org	ICPDR Secretariat
Stephane ISOARD	Stephane.Isoard@eea.europa.eu	EEA
Branislav Olah	Branislav.Olah@eea.europa.eu	EEA
Tiago Capela Lourenço	tcapela@siam.fis.fc.ul.pt	CIRCLE2 ERA-Net
Markus Leitner	markus.leitner@umweltbundesamt.at	CIRCLE2 ERA-Net mountain net
Sándor Szalai	szalai.sandor@mkk.szie.hu	Contractor Project 1 Carpathian Action

Alterra Wageningen UR
P.O. Box 47
6700 AA Wageningen
The Netherlands
T +31 (0)317 48 07 00
www.wageningenUR.nl/en/alterra

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The mission of Wageningen UR (University & Research centre) is ‘To explore the potential of nature to improve the quality of life’. Within Wageningen UR, nine specialised research institutes of the DLO Foundation have joined forces with Wageningen University to help answer the most important questions in the domain of healthy food and living environment. With approximately 30 locations, 6,000 members of staff and 9,000 students, Wageningen UR is one of the leading organisations in its domain worldwide. The integral approach to problems and the cooperation between the various disciplines are at the heart of the unique Wageningen Approach.

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Alterra Wageningen UR
P.O. Box 47
6700 AA Wageningen
The Netherlands
T +31 (0) 317 48 07 00
www.wageningenUR.nl/en/alterra

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Alterra Wageningen UR is the research institute for our green living environment. We offer a combination of practical and scientific research in a multitude of disciplines related to the green world around us and the sustainable use of our living environment, such as flora and fauna, soil, water, the environment, geo-information and remote sensing, landscape and spatial planning, man and society.

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