

MOUNTAIN ADAPTATION OUTLOOK SERIES

Outlook on climate change adaptation in the Carpathian mountains

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Piatra Craiului National Park, Romania

Foreword

Mountain ecosystems enrich the lives of over half of the world's population as a source of water, energy, agriculture and other essential goods and services. Unfortunately, while the impact of climate change is accentuated at high altitude, such regions are often on the edge of decision-making, partly due to their isolation, inaccessibility and relative poverty.

That is why the United Nations Environment Programme and partners have developed a series of outlook reports about the need for urgent action to protect mountain ecosystems and to mitigate human risk from extreme events. The series includes the Western Balkans, Southern Caucasus, Central Asia, Tropical Andes, Eastern Africa, and the Carpathian Mountains. The reports assess the effectiveness of existing adaptation policy measures and the extent to which they apply to mountain landscapes, going on to identify critical gaps that must be addressed to meet current and future risks from climate change. As a result of a broad assessment process involving

national governments and regional and international experts, the reports offer concrete recommendations for adaptation. This includes sharing regional good practices with the potential for wider replication to improve cost efficiency and adaptation capacity.

While each of the regions is covered in a dedicated report, they all face similar issues. On one hand, rising temperatures and changing precipitation patterns affect a range of mountain ecosystems, including forests, grasslands and lakes. On the other, drivers such as pollution from mining and unsustainable agriculture erode their ability to cope with these changes. The combined impact is increasing vulnerability among the local and downstream populations who depend on mountain ecosystems – especially when they are isolated from markets, services and decision-making institutions.

Shared by seven countries, the Carpathian region is a mountainous area of outstanding natural and cultural heritage. Like many other mountain

regions around the globe, the Carpathians provide a multitude of essential ecosystem goods and services that are particularly vulnerable to the impacts of climate change. Regional climate change projections suggest more irregular rainfall and a warmer climate in the Carpathians. According to recent findings, the Carpathian mountains will experience an increase of about 3.0-4.5°C during this century. Precipitation patterns will also change, leading to profound consequences on the environment, economy and human well-being. Thus, increased regional cooperation on common ecosystems will strengthen adaptation efforts, so we thank the governments of the Carpathian region for their support.

We hope that this report will serve as a practical companion for local, regional and national policy makers seeking to protect fragile mountain ecosystems and the people who depend on them.



A handwritten signature in black ink that reads "H. Egerer".

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Executive summary

Climate change is a threat to the Carpathian Mountains. The Carpathians are one of the most extensive mountain ranges in Europe, stretching across Central and Eastern Europe. The region is host to outstanding ecosystems such as virgin forests and grasslands. Which are hotspots for biodiversity and harbours large carnivores like bears, lynx and wolves. The Carpathians are also a crucial source of freshwater moving into three major rivers: The Danube and Dniester, flowing into the Black Sea and the Vistula, which flows into the Baltic Sea. Furthermore, the mountains are important for recreation and tourism. However, they are also highly sensitive to environmental change and extreme weather events. To maintain the unique ecosystems of the Carpathians, climate change adaptation policies are necessary.

Over the past decades, summer temperatures have increased by as much as 2,4°C in some parts of the Carpathians with an increase in the frequency and intensity of heat waves. Regional studies also indicate changes in precipitation patterns. Less precipitation in summer will result in lower river flows. However, more intensive short-duration precipitation is expected. During summers, more frequent drought periods will occur and there will be increased water scarcity. Furthermore, an increase in winter precipitation and changes in snow cover are predicted.

Impacts of climate change on mountains include shortened snow seasons and a climbing snow line, which threatens the local winter tourism industry, but

prolongs the growing season for agriculture. Earlier snowmelt will reduce river discharge and drinking water supplies during summer. Because of the increase in drought frequency during summertime, water scarcity and reduced groundwater recharge are likely. Frequent droughts will increase the risk of wildfires and vulnerability to pests in agriculture. Heavy rains from more intensive precipitation will lead to an increased risk of floods, erosion and landslides, which will affect livelihoods and settlements. If no adaptation to these hazards is undertaken, the region will suffer from economic and livelihood losses, impaired ecosystem functioning and loss of species.

The National Adaptation Strategies are the main policies for climate change adaptation. Furthermore, sectoral policies and strategies often include adaptation measures. This Outlook analyses these national and sectoral strategies, addressing the most pressing climate change related risks in the sectors of water, agriculture, forestry, biodiversity and tourism. These priority sectors were identified on the basis of the regional consultation meeting by the Working Group on Climate Change of the Carpathian Convention. Although existing adaptation actions already generate positive effects, there are still gaps to adapt to the identified key hazards. Policies must be developed to prepare for adaptation to future changes, as in general, current policies are more suited to cope with existing conditions. As an example, transboundary water and flood management policies are effective in addressing existing conditions but do not sufficiently take future projections into account. The European Union (EU)-member states





of the Carpathians have made similar progress in adaptation, due to the European harmonization of laws and guidelines. However, there is generally less funding and policy frameworks in Ukraine and Serbia, which are not EU members.

There is already a strong commitment to protect mountains, visible through the Carpathian Convention signed by all seven States. However, there could be more emphasis on mountains in national strategies. Until now, climate change impacts are mostly addressed in the tourism sector, due to the already perceptible reduction in snow cover. Better data collection and effective availability of information about local mountain specific impacts are necessary for targeted adaptation in this sensitive area. The framework of the Carpathian Convention is already a strong basis for sub-regional coordination of sustainable development in the region.

Methodology

This outlook is a synthesis and an analysis of existing climate change adaptation responses in the Carpathians and the extent to which they address key climate risks. It builds on information stemming from existing projects, reports and research literature. In addition, the latest climate change scenarios from the EURO-CORDEX initiative (Jacob et al. 2013) for temperature and precipitation were analysed. Identified key risks show the priorities that must be addressed by adaptation policies. Finally, it was examined how the existing measures respond to the key risks and which possible gaps remain for efficient adaptation.

Recommendations

The governments of the Carpathian countries already show awareness of the climate change effects and related hazards. The Carpathian Convention is the main driver for coordinated supranational policies towards a resilient and climate adapted Carpathian region. Several national or regional initiatives already address climate change related issues; nevertheless, further actions towards adaptation to climate change remain of crucial importance.

Increase focus on mountains in adaptation policies

As the Carpathians are particularly vulnerable to climate change, tailor-made adaptation measures

for mountains should be developed. With only a few exceptions, the countries in the Carpathian Region do not include mountain related measures in their adaptation policies. The value of mountainous regions is recognized in nearly all countries and stated in the national programmes. Yet there is a lack of concrete specific action for mountainous regions.

Strengthen the Carpathian Convention's mandate to improve cooperation on adaptation to climate change

The further strengthening of the Carpathian Convention's mandate is necessary to increase regional coordination and cooperation on climate

change adaptation. Implementing the targets of the Carpathian Convention protocols, developing common adaptation strategies, projects and activities is important for a sustainable future of the Carpathian Mountains. Supranational coordination, including with other institutions such as the International Commission for the Protection of the Danube River (ICPDR), is vital for successful preservation of the rich biodiversity and ecosystem services in the region for the mutual benefit of the parties.

Increase research on climate change and improve the integration of findings into decision making and development of adaptation policies

Key climate change hazards and vulnerabilities are mostly understood by scenarios based on scientific models, which project broad and probable trends of impacts for the future. However, further research and funding are needed to develop practical and evidence-based adaptation measures. The integration of scientific research into decision making and monitoring of progress are particularly important since climate change poses novel challenges. Carpathian countries should ensure that indicators and monitoring systems are uniform for comparability and efficient adaptation planning.

Increase awareness of climate adaptation among all stakeholders and ensure their active participation in decision making

Adaptation actions must be taken at all levels. Promoting awareness and knowledge sharing about climate change impacts and adaptation options is therefore essential. Furthermore, it is necessary to offer participation opportunities to all relevant stakeholder groups to ensure comprehensive adaptation.



Świnica Mountain, Poland

Support the development of sustainable adaptation in the fields of:

Water

- Adapt the management of existing water infrastructure, especially regarding overloads.
- Improve cooperation between land use and water resource managers.
- Protect ecosystems in the mountains to increase resilience to climate change and to ensure continued provision of their ecosystem services.
- Introduce rainwater harvesting systems and low-flow control that have local advantages like prevention of surface erosion and counteracting the degradation of forests.
- Produce integrated hazard zone maps, including the risk of flooding and landslides.
- Further harmonize Serbian and Ukrainian national legislation with relevant EU policies, especially applying the EU Floods Directive and the EU Water Framework Directive.
- Promote water retention capacity of agricultural land, such as by using natural fertilizers.

Agriculture

- Promote climate-smart agriculture, through adaptation measures including adaptation of sowing dates and crop varieties, improved water management and irrigation systems, adapted plant nutrition, protection and tillage practices.
- Recognize the value of agrobiodiversity as a cross cutting measure to increase the resilience of agriculture to climate hazards.
- Explore the use of technical agronomic innovations, such as robotics, sensor techniques or precision farming for adaptation to climate change.

- Facilitate the use of organic and natural fertilizers and decrease the spreading of pesticides and herbicides.
- Establish risk-sharing and risk-transfer mechanisms at the national level (e.g. weather-indexed insurance) to potentially reduce economic losses from climate hazards and improve resilience by contributing to prompt recovery.

Forestry

- Mainstream climate change issues into forestry, from education to policy and from monitoring to management planning.
- Promote ecosystem based approaches such as close-to-nature forestry to increase the adaptive capacity of forests.
- Harmonize forest monitoring systems, such as trans-national monitoring of invasive pests, at the regional level to provide information for adaptive forest management.
- Increase research of the opportunities and challenges of bioenergy production while at the same time maintaining the resilience of forests to climate change.

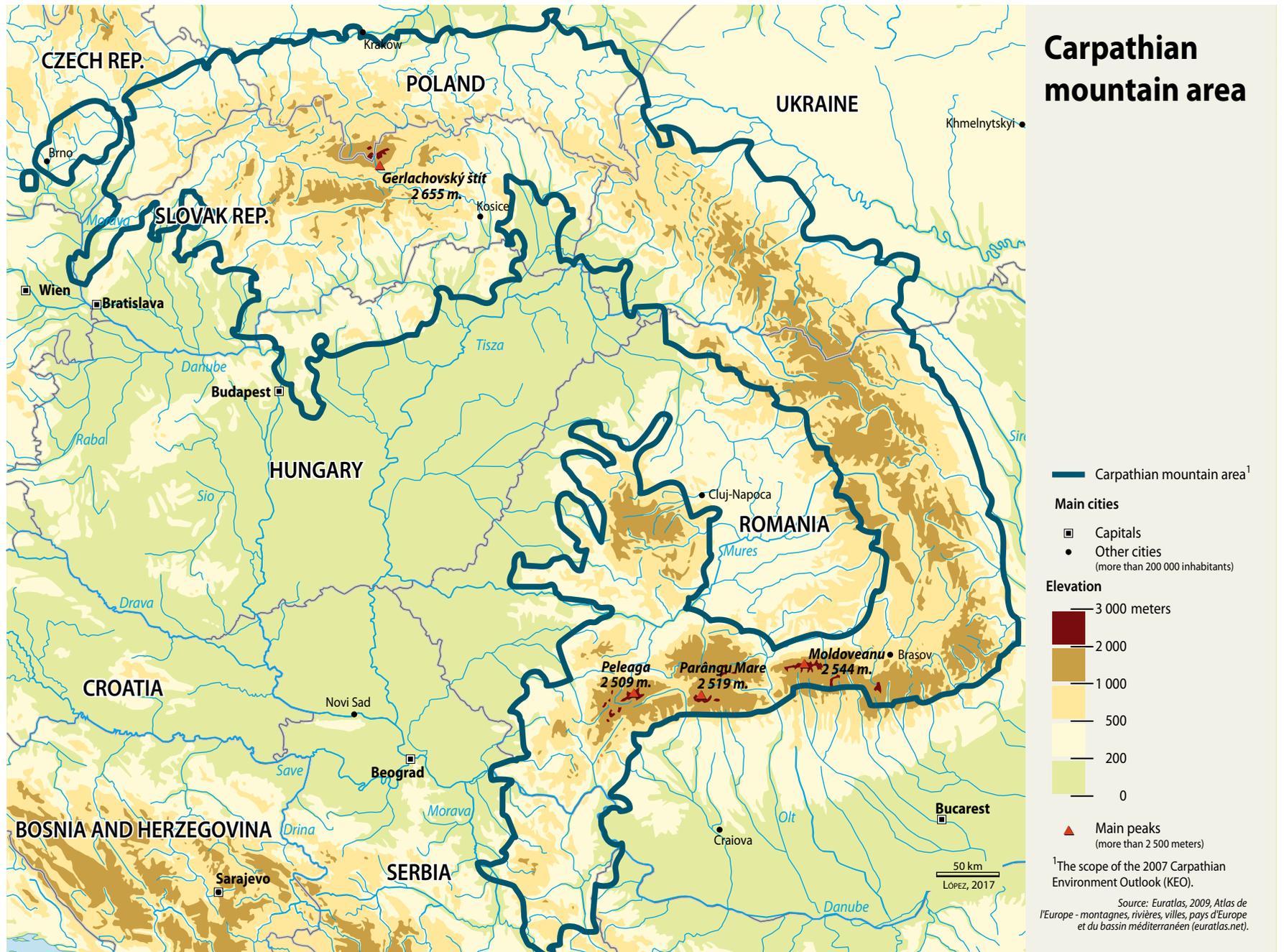
Biodiversity

- Promote ecosystem-based approaches for a resilient environment to reduce the impact of climate change and promote the conservation of biodiversity.
- Integrate wetland protection in flood control practices and promote the restoration of peat- and wetlands, floodplain rehabilitation and creation of new wetlands and lakes for an enhanced local water retention capacity and for supporting biodiversity.
- Support protected area management in adapting to climate change.

- Increase ecological connectivity through ecological networks and protected areas to facilitate the migration of species in response to climate change.
- Protect endangered flora and fauna to ensure a rich genetic diversity.
- Take further measures to reduce the impact of invasive species.

Tourism

- Consider climate change when planning tourism strategies and new investments to avoid financial losses.
- Diversify tourism (e.g. ecotourism, cultural tourism, health tourism, or conference tourism) to avoid dependency on snow cover and to promote year-round income.
- Avoid trade-offs between environmental protection and adaptation measures in tourism, such as by using energy intensive snow machines.



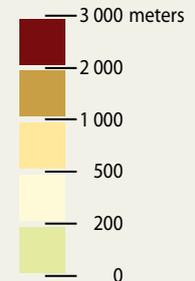
Carpathian mountain area

— Carpathian mountain area¹

Main cities

- Capitals
- Other cities (more than 200 000 inhabitants)

Elevation



- Main peaks (more than 2 500 meters)

¹The scope of the 2007 Carpathian Environment Outlook (KEO).

Source: Euratlas, 2009, Atlas de l'Europe - montagnes, rivières, villes, pays d'Europe et du bassin méditerranéen (euratlas.net).

CARPATHIAN MOUNTAINS

Climate change in the Carpathians

Malá Fatra, Slovakia

Climate change in the Carpathians

The Carpathians consist of a chain of mountain ranges, forming an arch from the Czech Republic in the northwest through Slovakia, Poland, Hungary, and Ukraine to Romania in the east and Serbia in the south. They cover an area of about 210,000 km² (Werners et al., 2014). The Carpathian macro region stretches beyond the area of the Carpathian Mountains and extends for approximately 450,000 km². The Carpathian climate is influenced by both Western and Eastern winds. In the winter, it is governed by the inflow of polar continental air masses from east and northeast. In summer, oceanic air masses from the west predominate. The continental character of the climate is clearly seen in Transylvania, the centre of Romania, and the lower parts of the southern slopes due to the distance from the Atlantic Ocean.

Around 17 million people live in urban centres and remote mountain areas in the region (Fnukal et al., 2009). The density is higher in the lowlands partly due to more difficult economic conditions in the highlands (Illès, 2007). Due to the long-time frame of climate change, it is important to understand it in combination with economic and demographic changes. For example, if an area is expected to have less water, it is important to know if there will also be more people and demand to plan water management efficiently. Urbanization rates are relatively low in the Carpathian countries.

Relative to urban areas, rural areas have higher levels of poverty. Rural populations are generally in

decline, largely because of migration in the search for employment. Many inhabitants of the rural southern and eastern Carpathians still live in a subsistence economy with the traditional forms of grazing cattle, sheep and horses. Agriculture produces only up to 10% of the GDP in these countries, but is nevertheless important for the economy. Although forestry contributes less than 5% to the GDP in the Carpathian countries, logging and wood processing is also of major importance in many areas. (Hajdúchová et al., 2016; Lakatos et al., 2013).

Social factors are important for determining degrees of vulnerability to climate change. People with limited access to funds, government institutions or social safety nets have fewer adaptation options and are more likely to suffer from the impacts of climate change. Most of the Carpathian region's poor now live in rural areas (Pomázi & Szabó, 2010). Furthermore, poverty-related problems in the rural mountainous communities are often exacerbated by remoteness from markets and services. Sexism, social exclusion and discrimination are other central factors for vulnerability. Women often earn less money, which means adaptation is relatively costlier. Another notable example of social vulnerability in the Carpathians is how Roma people often live in some of the poorest regions of their respective countries, suffering from high unemployment and economic underdevelopment (Pomázi et al., 2006). Addressing these concerns is becoming an increasingly important socio-political issue for national and sub-regional governments. Environmental and social vulnerabilities combine to create risks for mountain communities in the face of climate change.



Hungary

Trends and scenarios

Observed climatic changes

Current observations show that temperature is clearly rising in the Carpathians. The most warming is observed in summer (between 1.0° and 2.4°C) with an increase of the frequency and intensity of heat waves. The temperature increase shows a gradient from less increase in the East to more increase in the western part of the range. In winter, there is a slight decrease of temperatures in the east and south and a slight increase of only about 0.4°C in the northern and western parts (Werners et al., 2014a). With respect to more extreme events, the number of hot days is increasing, whereas extreme cold temperatures are decreasing in the western part and increasing in the north-eastern part of the region (Spinoni et al., 2015).

Changes in rainfall have a high spatial and temporal variability. There is an observed decrease in western and south-eastern parts of the region and an increase in the north and northeast. During the 1961–2010 period, every part of the Carpathian region on average experienced between half and six drought months per year (Antofie et al., 2015). Nevertheless, the sum of precipitation is increasing in summer and winter and decreasing in spring.

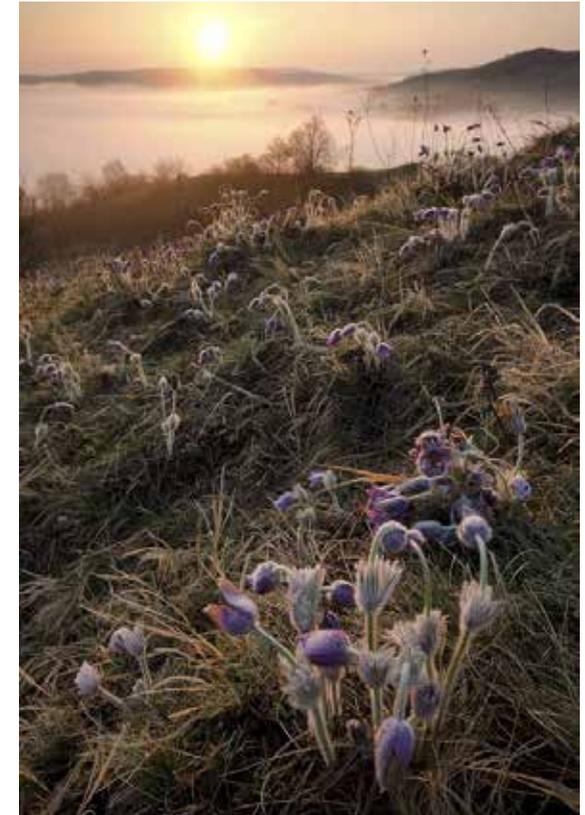
Projected Scenarios

For this report, we analysed temperature and precipitation projections from the 1971–2000 timeline to the near (2021–2050) and distant (2071–2100) future. The analysis was based on the mean of 12 different regional climate models from the EURO-CORDEX initiative (Jacob et al. 2013). Furthermore,

we took two different Intergovernmental Panel for Climate Change (IPCC) concentration scenarios into account: the scenario Representative Concentration Pathway (RCP) 4.5. is a more optimistic one, assuming a greenhouse gas emission peak in the year 2040 and a decline after; the RCP 8.5. is less optimistic, assuming a continuous increase of greenhouse gas emissions in the 21st century. Which scenario will play out in reality depends on global mitigation efforts.

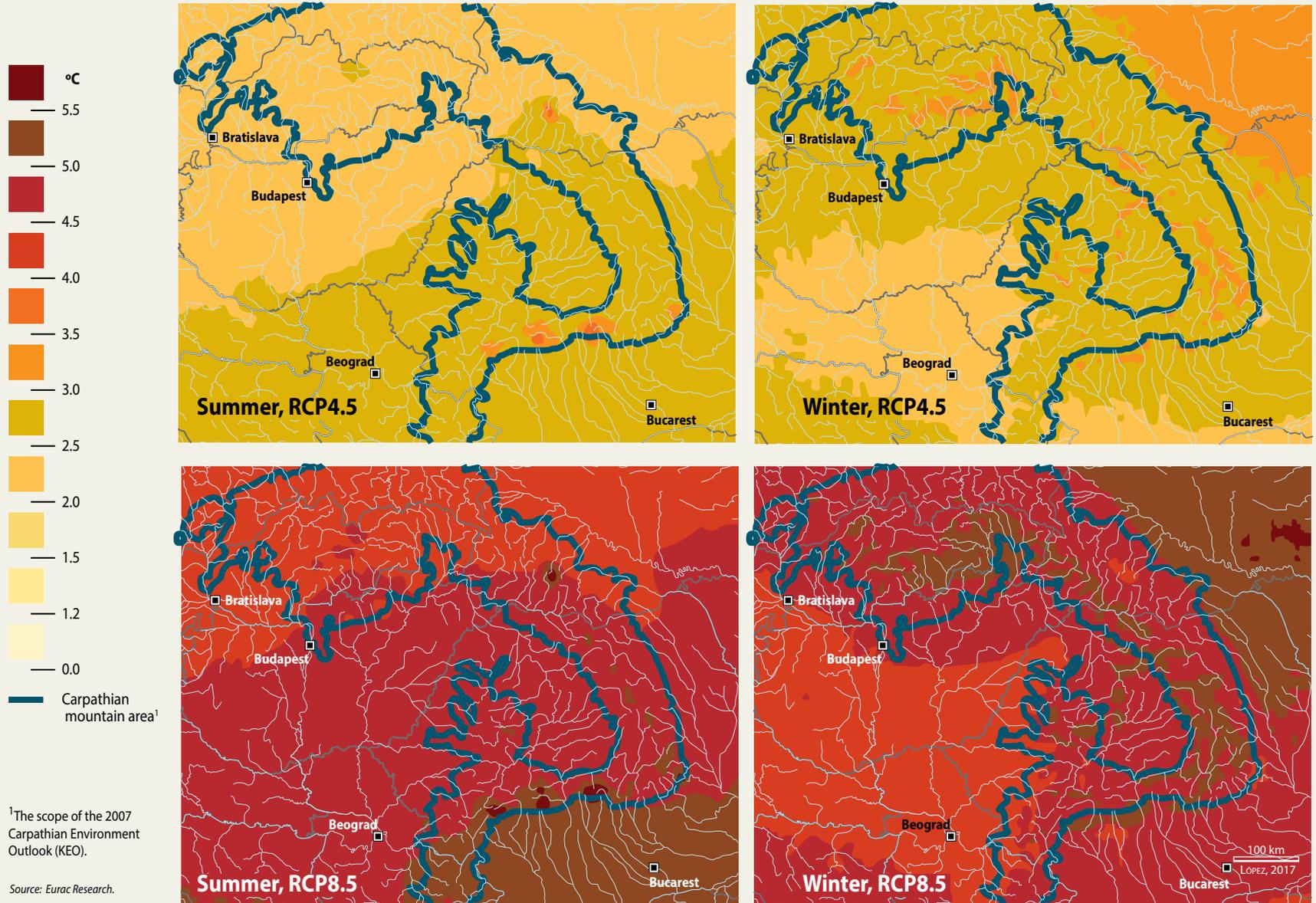
A warming trend is shown in all the scenarios for the entire region (see Figures). Both summer scenarios show an increase of 1.2°C in the North and up to 2°C in the South in the first half of the 21st century. In winter, there is a higher temperature increase in the East than in the West. The highest temperature increase, according to the model calculations, are expected in the Southern mountain ranges. The amount of winter days strongly depends on the elevation. In the second half of the century, the temperature increase is higher. The RCP 4.5 scenario shows a temperature increase of about 2–3 °C whereas the RCP 8.5 scenario results show temperature increases in summer and winter of up to 5°C.

Precipitation is projected to decrease in summer, particularly in the south and in the mountains by up to -20mm per month. However, the trend is less clear in the short-term projections. Projections of winter precipitation show an increase of up to +20mm, particularly in the north. The amount of rainy days will decrease in the south and increase in the northeast, particularly during summers. The projections show more periods of intense precipitation, which cause

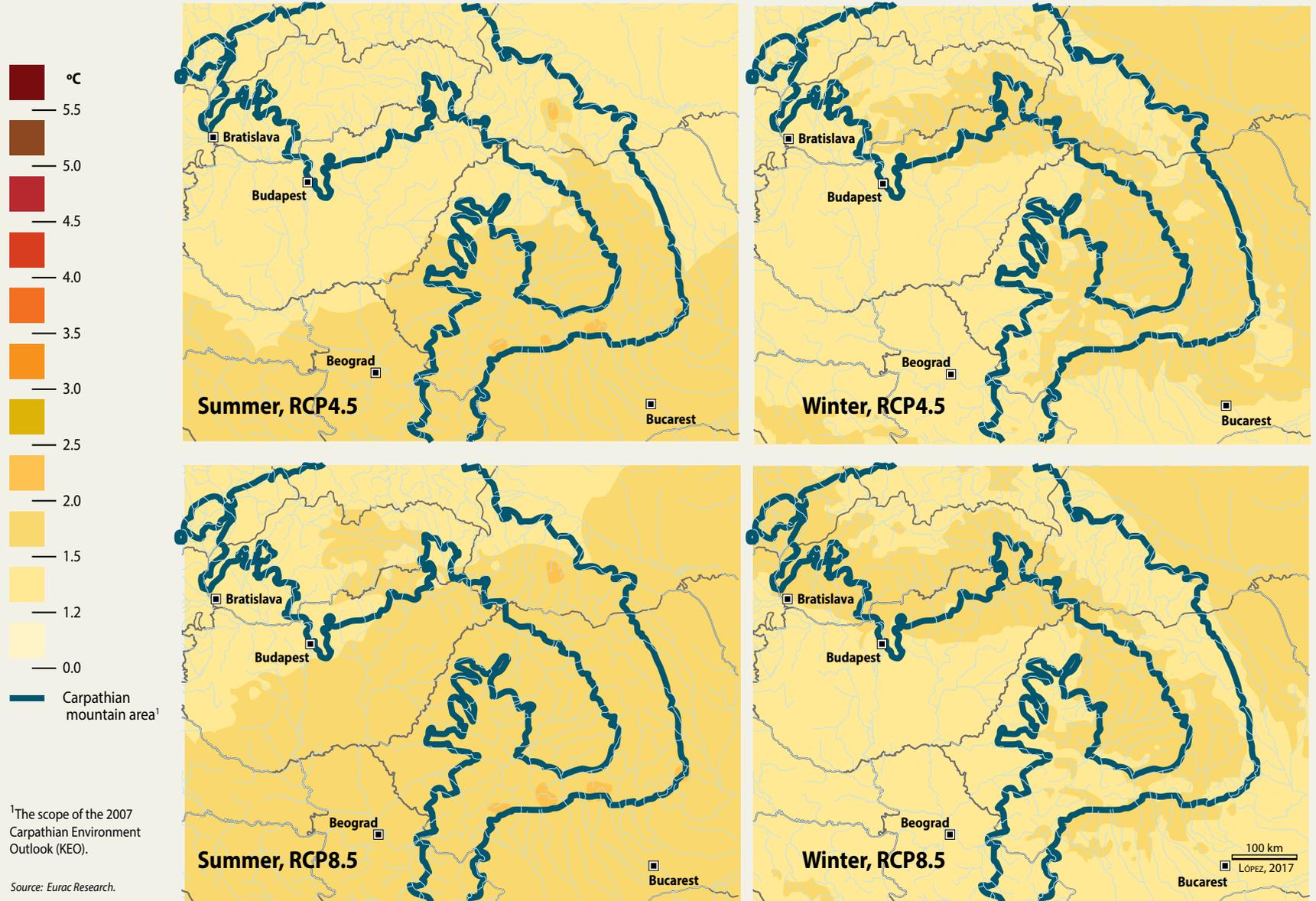


more runoff and less infiltration due to less frequent but more intensive precipitation events. This precipitation trend combined with less water from snowmelt, higher temperatures in summer and, as a result, higher evapotranspiration losses will lead to a higher risk of summer droughts all over the region. Both, the frequency and severity of drought events are expected to increase in the whole Carpathian region (Werners et al., 2014a).

Projected changes in mean temperatures for 2071-2100 and the forcing scenarios RCP4.5 and RCP8.5. Reference period 1971-2000



Projected changes in mean temperatures for 2021-2050 and the forcing scenarios RCP4.5 and RCP8.5. Reference period 1971-2000



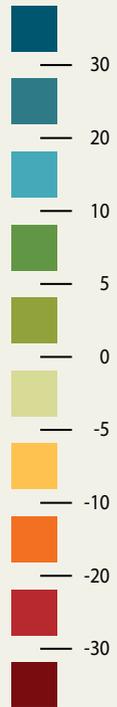
¹The scope of the 2007 Carpathian Environment Outlook (KEO).

Source: Eurac Research.

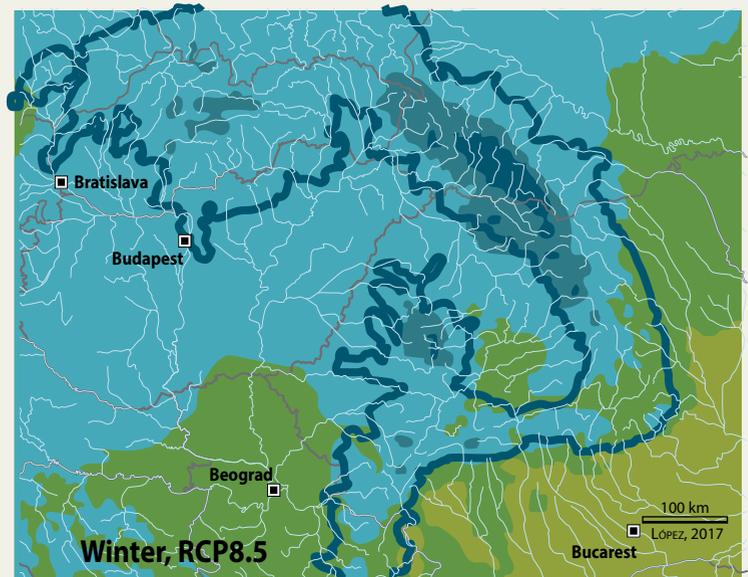
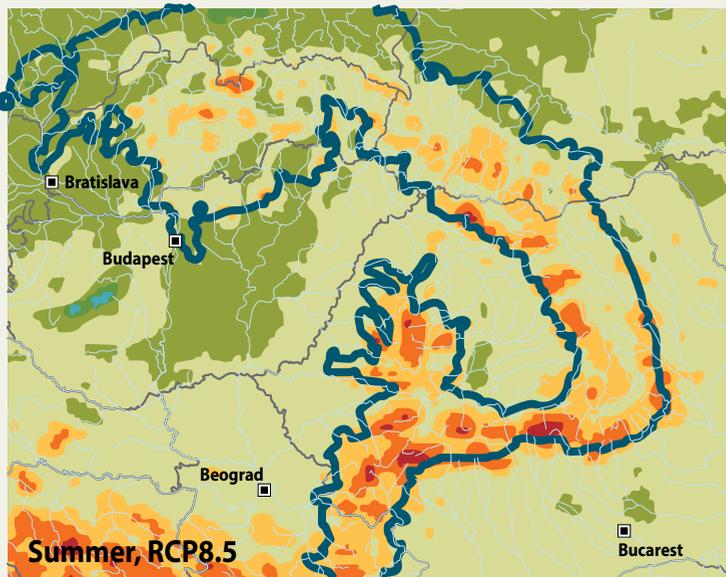
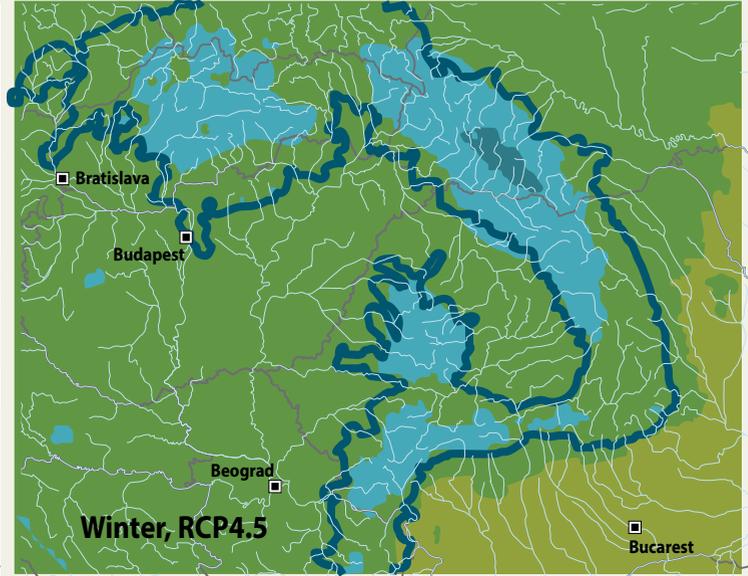
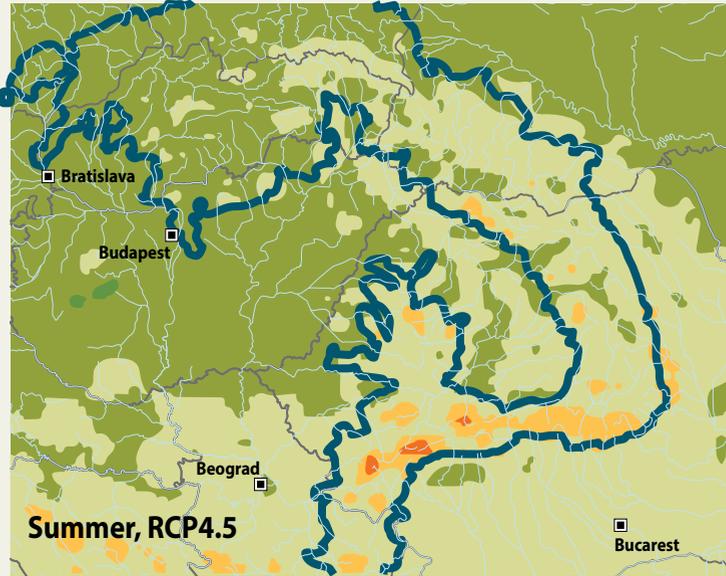
Projected changes in mean precipitation

per month for 2071-2100 and the forcing scenarios RCP4.5 and RCP8.5. Reference period 1971-2000

Millimeters



Carpathian mountain area



¹The scope of the 2007 Carpathian Environment Outlook (KEO).

Source: Eurac Research.

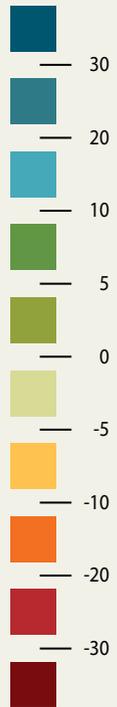
100 km

LOPEZ, 2017

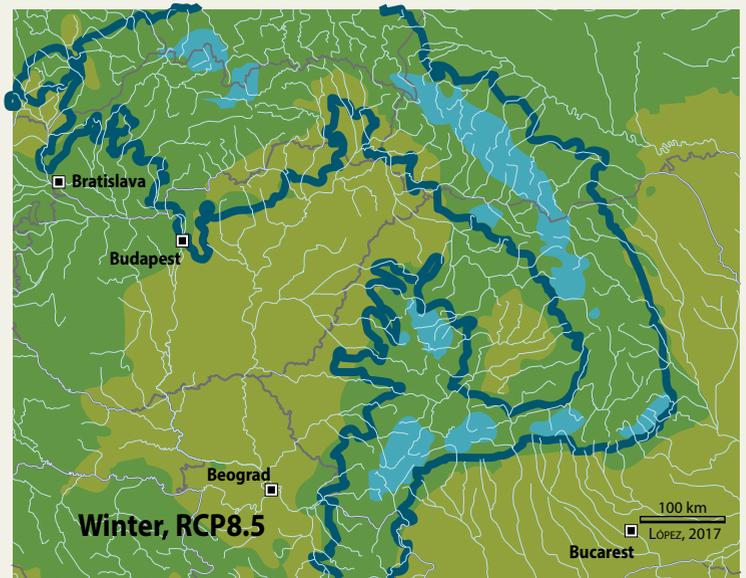
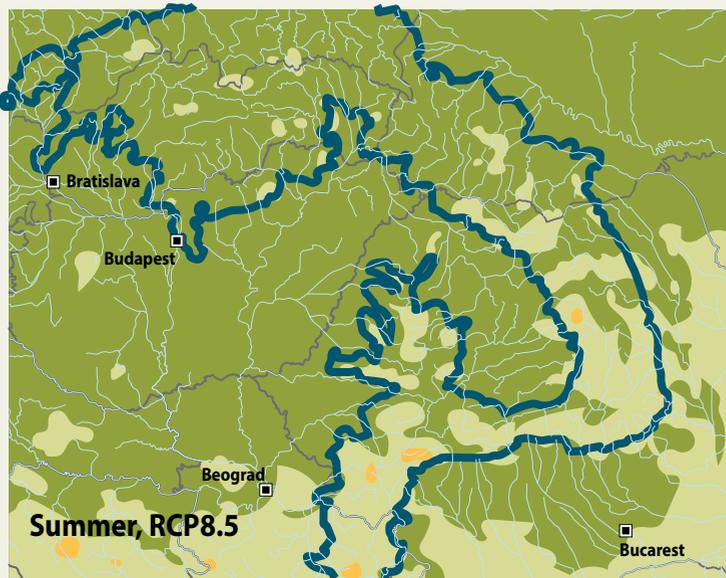
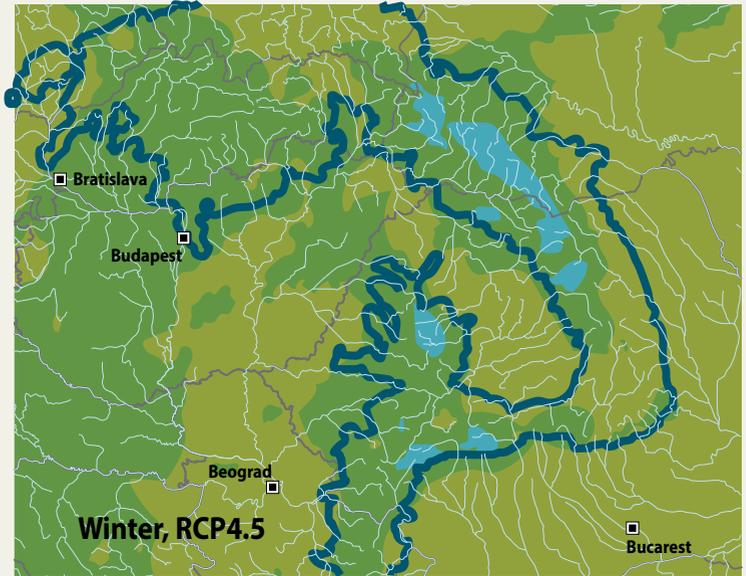
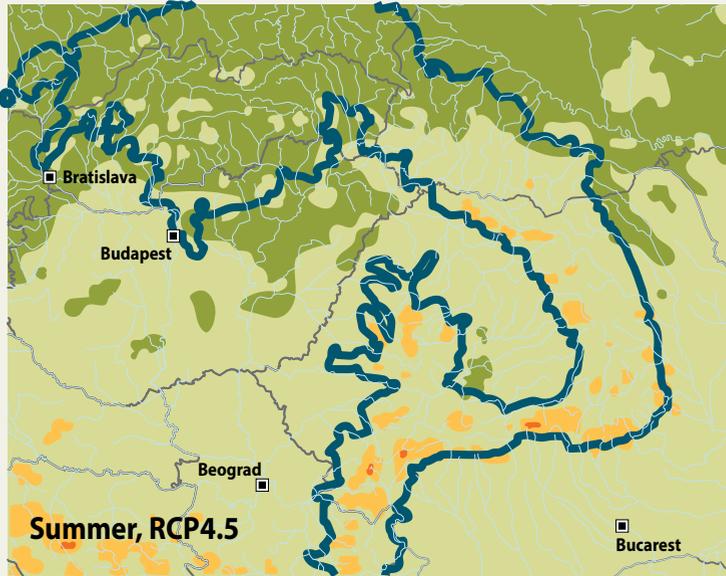
Projected changes in mean precipitation

per month for 2021-2050 and the forcing scenarios RCP4.5 and RCP8.5. Reference period 1971-2000

Millimeters



Carpathian mountain area¹



¹The scope of the 2007 Carpathian Environment Outlook (KEO).

Source: Eurac Research.



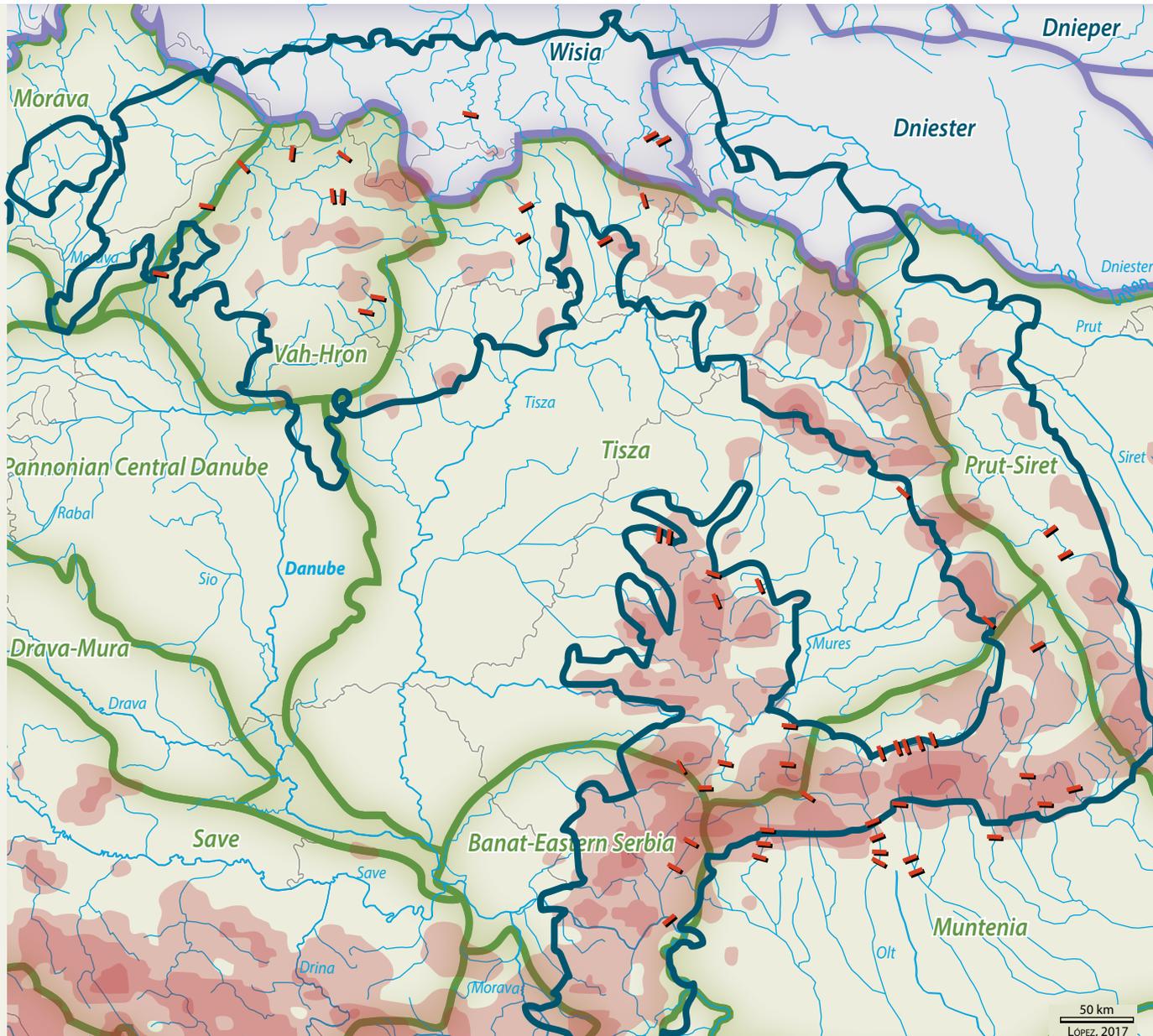
Tatra Mountains, Slovakia

CARPATHIAN MOUNTAINS

Key risks for relevant sectors and ecosystems

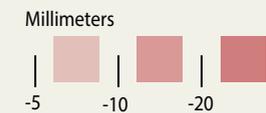
Piatra Craiului National Park, Romania

Water and Climate change



-  Carpathian mountain area¹
-  Hydropower plants
-  Danube river sub-basins
-  Other river basins

Projected changes in mean precipitation
per month for 2071-2100, during the summer, and for the forcing scenario RCP8.5. Reference period 1971-2000



¹The scope of the 2007 Carpathian Environment Outlook (KEO).

Source: Aquastat, 2015, Geo-referenced dams database, Fao; Schwartz U., 1999, Danube Sub-river Basins, UNDP; Novikov V., 2007, Water basins of Eastern Europe, UNEP/GRID-Arendal.

Water

The uses of water for drinking, agriculture and livestock, energy production, industry, shipping and tourism play a key role in the Carpathian region. The projected increase of droughts will have a major impact on water resources. Over 80% of water for human consumption in the Carpathians is supplied by groundwater. The Carpathian highlands are important for surface runoff generation and for providing water resources. There are no glaciers within the Carpathians, but permafrost and small yearlong snow areas can be found in the High Tatras. Many other mountain ecosystems regulate the hydrology of the region, such as wetlands and forests. The largest river is the Danube with its tributaries Váh, Tisza, Olt, Siret, and it is easterly flanked by the Prut and Dniester, which both drain into the Black Sea. In the northern slopes of the Carpathians, in Poland and parts of Slovakia, a small area is linked to the Baltic Sea by the Vistula and Oder rivers.

As a mountainous region, the Carpathians benefit from hydropower. Over the years, the hydropower resources in the Carpathians have been almost fully exploited. The highest share of energy production in the region is produced in Romania (about 30%), while in Ukraine, it is 10%. The EU member states in the Carpathians have adopted national targets to contribute to reaching a 20% proportion of hydropower for electricity production for the entire EU (European Commission, 2009). Increased temperatures and less precipitation will lead to runoff reduction. Extreme events such as severe droughts and floods also endanger non-renewable power plants that are situated at the rivers and depend on sufficient water levels.

Man-made impacts on water in the area are mainly caused by inadequate water management. Nutrients and other organic matter drain into water bodies from agricultural sites. In addition, the water quality

is reduced by waste water from households and industry. Floods or industrial accidents as well as contamination from mining activities pollute many rivers in the area with heavy metals. The existing water shortage originates from over-exploitation of surface and groundwater resources and changes

in the river flow patterns. Even though most river basins stretch over borders, little exchange of information exists on a larger scale. Monitoring systems operate only in individual countries and in some transboundary catchments, but not on the Carpathian scale.



Tatra Mountains, Slovakia

Climate change will exacerbate pressures on water resources and will pose risks in sectors where water is a limiting factor, including agriculture, industry and tourism (Werners et al., 2014a). In periods of low precipitation and high temperatures, less river runoff will increase eutrophication and could trigger toxic algal blooms (UN Environment, 2014). Higher temperatures in winter will more often result in rain, affecting snow cover. Consequently, this might lead to melting of the small yearlong snow patches in the High Tatras.

Changes in rainfall combined with more extreme events will lead to less infiltration. Groundwater recharge will be reduced, whilst more frequent droughts in the summer will result in water shortages when the demand is the highest (UN Environment, 2014). Precipitation will generally decrease in spring and during summer heat waves. Water shortages will cause irreversible damage to aquatic and riparian ecosystems, agriculture and industry. An intensification of extreme precipitation produces surface runoff and increases the risk of erosion. The loss of top soil increases the risk of desertification and can expose the population to excessive runoff, landslides, floods and wildfires. The increased flood risks will not only affect infrastructure, but also endanger water quality due to possible failure of existing wastewater treatment plants during flood events.

Agriculture

The features of the mountainous landscape shape agriculture in the Carpathians. Crops are restricted to the valleys and lower altitudes, while higher grasslands are suitable for animal husbandry. Since 1990, the collapse of the communist regimes in some areas led to a decrease in state support, and

land reforms led to privatization and restitution of agricultural land, resulting in small fragmented farms. These changes, which occurred at the same time as noticeable emigration to Western Europe, affect agricultural production and cause significant and persisting abandonment of cropland (Munteanu et al., 2008; Griffith et al., 2013). Although its share of the gross domestic product is on average less than 10% in all the countries (Werners et al., 2014a), agriculture is still important in the Carpathian region, in particular for rural employment.

The proportion of people working in agriculture differs among the countries. Romania has the highest rate with about 25%, Serbia (19%), Ukraine (15%), Poland (12%), Hungary (5%), Slovakia (3%) and Czech Republic (2%) (World Bank, 2015). Most farms are small and lack modernization. The ageing labour force and rural depopulation are challenges for rural agriculture. The share of the area suitable for efficient crop production is small. Currently, most cultivated crops in the Carpathians are rain-fed with little or no irrigation. On the northern slopes, predominantly wheat, rye, oats, and potatoes are cultivated; on the southern slopes: corn (maize), sugar beets, grapes, and tobacco (Kondracki, 2014).

Agriculture is sensitive to changes in precipitation, temperature and length of seasons. Crop cultivation practices might have to be adapted, such as through changes in species or rotation. Due to higher temperatures, there might be a shift in cultivation from less wheat to more sunflower and soy during summer seasons. Likewise, winter wheat cultivation might increase (Werners et al., 2014a). Nevertheless, reduced water availability, especially in spring, and the danger of droughts as well as extreme weather events will decrease yields and reduce areas suitable for cultivation (Olesen & Bindi, 2002).

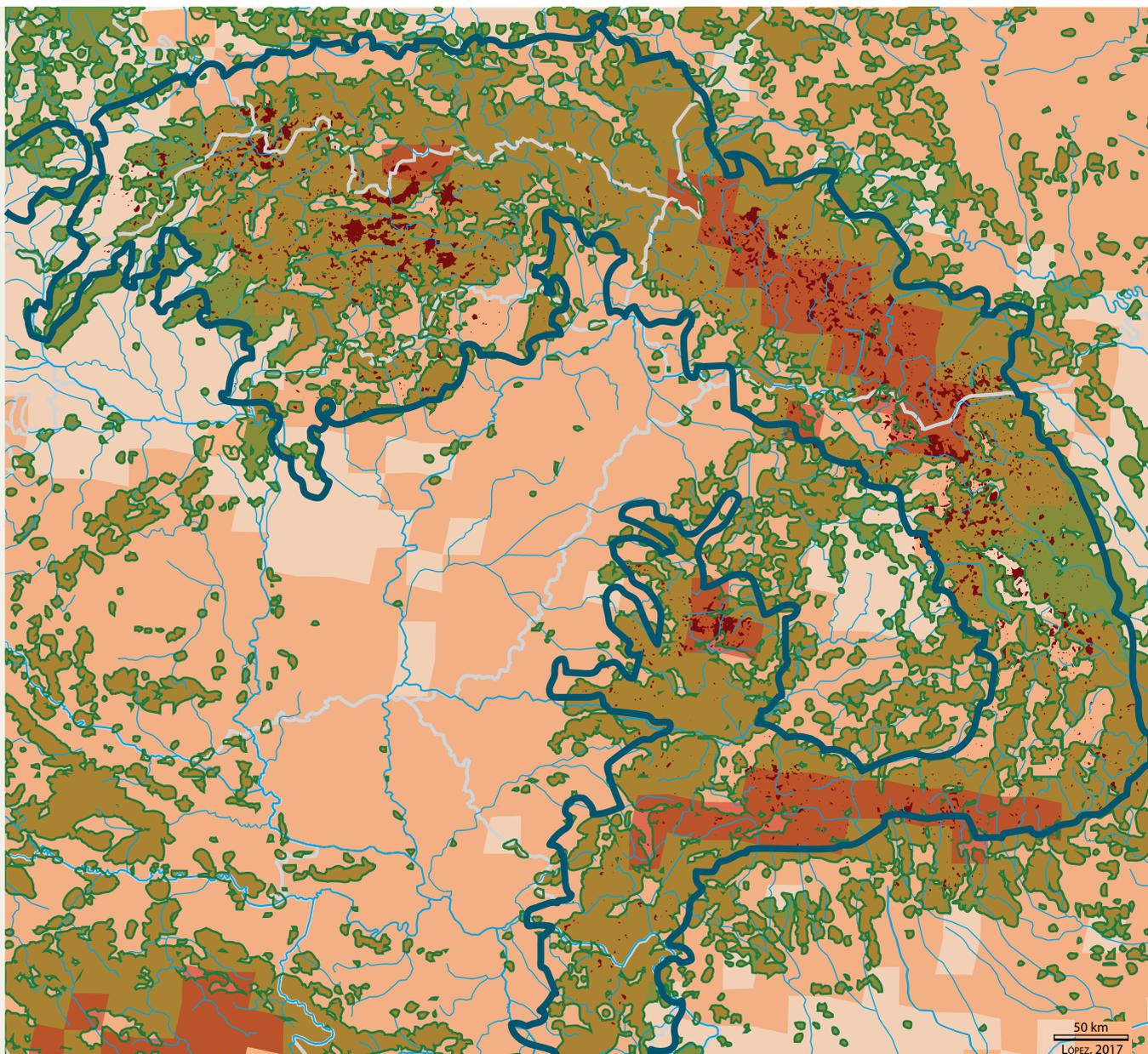
There may be some advantages from climate change: crop cultivation may become feasible at higher altitudes; the growing season will be longer and certain plant productivity might increase. Moreover, climate change may result in the cultivation of permanent cultures such as wine grapes in the western Carpathians (Kovacs et al., 2017). Nevertheless, the imminent droughts during the vegetation period, a higher risk for pests, soil erosion, groundwater depletion and extreme rainfall are likely to counterbalance the positive effects from climate change (Werners et al., 2014a).

Above 900 m, forestry and pastoralism are the main livelihoods. Pastures are an indispensable part of the Carpathian agro-forestry culture for food, water purification and for providing habitats. The share of grassland is about 20-30% in the Romanian and Ukrainian Carpathians and less on the higher altitudes in Slovakia. Degradation is visible in higher elevations, where overgrazing leads to patchy vegetation prone to erosion. In the future, land abandonment is a more likely scenario than the intensification of livestock production, although a combination of the two could potentially occur (Borsa et al., 2009; Nuppenau et al., 2011). When leaving the pastures unmanaged, the arable land will decrease due to invading bushes and a rising tree-line (Calaciura & Spinelli, 2008). Measures, such as nature conservation and agricultural policies, have been taken for preserving the grasslands; in some places, they resulted in a shift from arable land to ecologically high-value mountain meadows and from forests to pastures. (Munteanu et al., 2014). The impact of climate change on the pastures depends on water availability. Less water and greater heat will endanger the wellbeing of livestock as well as mountain species, who are threatened by global warming (Coldea et al., 2009). However, grassland productivity could also improve with warmer temperatures if there is sufficient water.



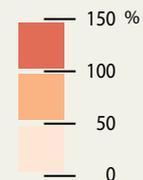
Tisza valley, Ukraine

Forests and Climate Change



- Carpathian mountain area¹
- Forest cover
- Deforestation 2000-2015

**Projected change
in forest fire danger
for 2071-2100**
Reference period 1961-1990
Change in
Seasonal Severity Rating (SSR)



¹The scope of the 2007 Carpathian Environment Outlook (KEO).

Sources: Joint Research Center, 2016, European Union; Borsa M. et al., 2009, VASICA: Visions and strategies in the Carpathian Area, The Carpathian Project; Hansen et al., 2016, Global Forest Change, University of Maryland.

Forestry

The Carpathians contain the largest continuous forests in Europe. On average, 75% of the Northern Carpathians and 66% of the entire region is covered by woods (Borsa et al., 2009). Half of the Carpathian forests is in Romania. The region provides an important refuge and corridor for the migration of diverse species and hosts exceptional biodiversity. The Carpathian forests are the largest pristine forests in Western and Central Europe. Forestry is crucial for the economy of many local communities. People in rural areas rely on firewood and use the forests for additional income. The prevailing demand for wood is visible in the young age of the forest: only about 11% is mature forest and over 50% is young and deforested (ibid). Effects of past management, land ownership and institutional changes can persist for centuries, and affect forest ecosystem composition, health and structure, and consequently ecosystem services and habitat availability (Munteanu, 2016).

Forests are important for the sustainability of the landscape. They mitigate greenhouse gases and provide resilience to climate hazards by regulating soil and water regimes as well as protect biodiversity. Carbon sequestration is an important service provided by forests. They remove carbon from the atmosphere as they grow, contributing to climate change mitigation. There is a possible conflict between adaptation and mitigation in the forestry sector. The use of biomass for energy production has been offered as an option for climate change mitigation, however it is unclear whether this will make forests less resilient to climate hazards due to increased harvest. The projected rate of forest adaptation is insufficient to secure the sustainable provisioning of desired ecosystem services under climate change; a greater intensity of adaptation actions is required (Hlásny, 2017).



Recent studies suggest that climate change will lead to the local extinction of many tree species during this century, affecting the functioning and ecosystem services of many forests (Somogyi, 2017). Forests are under pressure due to intensification of forestry, agriculture and infrastructure. The amount of forest has declined because of formal wood harvesting, but also illegal logging. Forests face increased pressure from invasive species, especially in the South-Western slopes (Simpson, 2011). Native trees could be further replaced, which is particularly problematic for vulnerable alluvial forest. In addition, some of the forest stands have been damaged from wind, insect pest

outbreaks, as well as increasingly recognized effects of droughts that can trigger forest fires (San-Miguel-Ayanz et al., 2015). For example, Norway spruce forests of the Carpathian High Tatra Mountains have been subject to unprecedented tree mortality caused by attacks of the Eurasian spruce bark beetle in recent decades (Mezei et al., 2017). The expected droughts will also lead to a higher vulnerability to storms and top soil erosion as forests will be less resilient (Kazakova & Popp, 2009). The most vulnerable species to rising temperatures in summer include spruce, the Scotch pine and the European larch (Lindner et al., 2008; Szweczyk et al., 2011).

Biodiversity

The Carpathians are widely recognized as an important biodiversity hotspot for mountain species in Europe (Stewart, 2009), including rich native flora and many rare animals. About one-third of all European vascular plants, representing 4000 species, grow in the Carpathian area. The biodiversity of invertebrates and fungi in the woods is especially remarkable. Different bird species, including migrating birds and owls have been registered in the area. Red deer, roe deer, chamois, brown hare, otter, bats and many other species are living in the area. The region is also home to one of the biggest populations of large carnivores in Europe, such as wolf, lynx, wildcat and brown bear.

Due to its diverse landscape, the Carpathian Mountains host a vast variety of natural and semi-natural ecosystems, including forests, grasslands, pastures and wetlands. The changes in CO₂ concentrations as well as temperature and precipitation regimes will



Red fox

affect the physiological processes of fauna and flora (UN Environment, 2014). There are few studies on the effects of climate change on mountain ecosystems, especially in the Carpathians (Bálint et al., 2011). Nevertheless, some of the research of other mountain areas can be applied to the Carpathians. The results show that the expected climate change will have a noticeable impact on the biodiversity (Thullier, 2007; Mooney et al., 2008). The displacement of natural boundaries and the loss of natural ecosystems, including the corridors for migration of rare and endemic species, might be the consequences.

Climate change will probably lead to an upslope climbing of the tree line, which will affect the species composition of grassland ecosystems. As grasslands often host rarer and more fragile species than bushes and forests, this would lead to biodiversity losses (Pellissier et al., 2012; Niedrist et al., 2009). Ecosystems on limy soil are more species-rich and more sensitive than vegetation on other substrates (Werners et al., 2014b). Other species try to adapt by changing their phenology.

Higher temperatures and less water during the vegetation period will threaten wetland ecosystems. Peatlands, small streams, wells and floodplains are especially at risk because they have a low drought resilience (Werners et al., 2014b). Wetland loss would also reduce habitats for the many dependent plants and animals and lead to habitat fragmentation that could threaten migration of animals on a regional scale (UN Environment, 2014). Furthermore, it will influence the carbon cycle, the emissions and uptake of greenhouse gases. Warmer and shorter winters will also affect animal hibernation. As this period will probably get shorter, the food demand of these species will rise. Furthermore, species that are currently living in protected areas could have to migrate or adapt to survive.



Red deer



Tourism

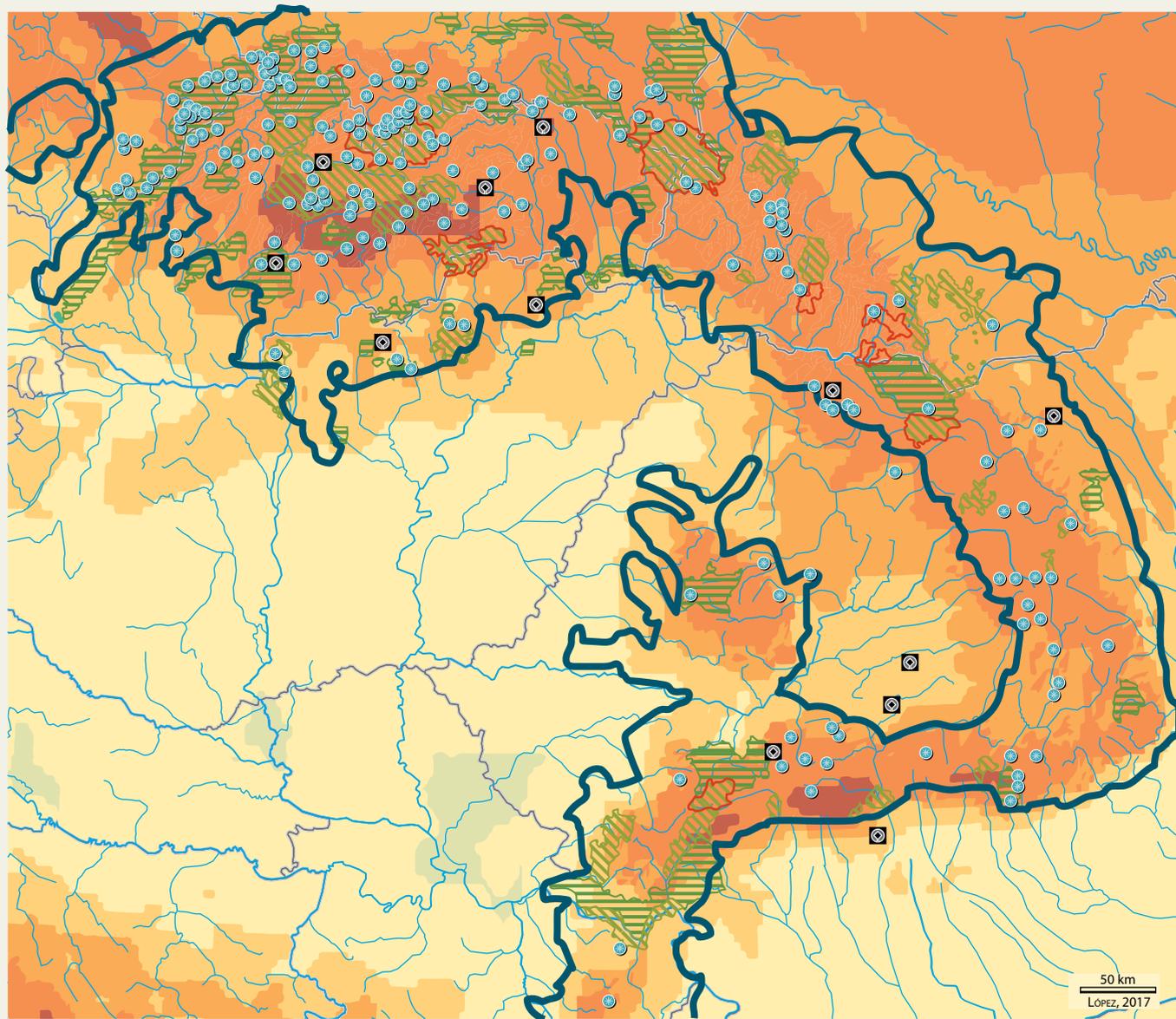
The Carpathians are a popular tourist destination, due to their cultural heritage and natural beauty. Tourists come predominantly in winter and summer seasons. Spa and health resorts are offered all year long due to the abundance of mineral water sources. In the year 2011, approximately 31 million overnight stays were recorded, generating about 7-12% of the region's GDP (Werners et al., 2014b). Winter tourism is focused on outdoor winter sports. The significance of winter tourism for the economy has increased in Slovakia, Romania and Ukraine, where more new ski resorts have been built after the breakdown of the communist regimes. Expected higher temperatures in winter are

threatening the snow reliability as well as the potential for artificial snow. In the future, only the skiing areas at higher altitudes or areas in the northern part of the mountains will be able to provide enough snow (Lapin & Fasko, 2005; Micu, 2009). A decrease in snow cover is expected and noticeable at the beginning and the end of the skiing seasons, shortening the winter tourism period. Climate change might both disadvantage and advantage tourism in the area. The mountain areas could benefit if tourists decide to escape the hot lowlands, like the Mediterranean (EC, 2007b). Climate change will result in longer summer tourist seasons. On the other hand, the increase of extreme events might cause flash floods, landslides or forest fires that will disadvantage tourism.



Tatra Mountains tourism

Tourism and Climate change



— Carpathian mountain area¹

● Ski resorts

⊠ World Heritage sites (UNESCO)

Protected areas

▨ Landscape Parks

▨ National Parks

▭ Biosphere Reserves

Projected changes in days with snow cover
per year for 2021-2050, and for the forcing scenario RCP8.5.
Reference period 1970-2000



¹The scope of the 2007 Carpathian Environment Outlook (KEO).

Sources: Eurac Research; Carpathian Network of Protected Areas (CNPA), 2017, Protected Areas Map (carpathianparks.org); Skiresort.info, 2017, Ski resorts Carpathian Mountains, (skiresort.info); Carpathian Convention Website, 2017, UNESCO, World Heritage sites (webgis.eurac.edu).

Summary of key hazards, vulnerabilities and risks

Hazard	Vulnerable sectors	Key risks
Flooding	All sectors	<ul style="list-style-type: none"> • Threat to human health and lives • Damage to buildings and infrastructure • Loss of agricultural production • Sewage overflow • Decrease of water quality • Threats to species and ecosystems • Outbreaks of diseases • Higher flood risk during winter due to reduced snow cover
Wildfires	All sectors	<ul style="list-style-type: none"> • Threat to human lives and property • Losses in biodiversity • Degradation of land and ecosystems • Risks inducing landslides and soil erosion
Water scarcity, Droughts	Water	<ul style="list-style-type: none"> • Drinking water shortages • Decrease of water quality • Less groundwater recharge • Lower productivity of hydropower
	Agriculture	<ul style="list-style-type: none"> • Crops have a limited tolerance for heat • Losses in crop production • Stress on animal husbandry • Economic losses
	Forestry	<ul style="list-style-type: none"> • Reduced wood production • Higher susceptibility of the forest for insect attacks, pathogens and fires • Economic losses
	Biodiversity	<ul style="list-style-type: none"> • Stress for wetland and terrestrial ecosystems • Potential loss of peatlands, small streams, wells and floodplains • Stress for rare, endemic and vulnerable species • Changes in species composition in the mountain grasslands • Economic losses
	Tourism	<ul style="list-style-type: none"> • Less attractive landscapes



Summary of key hazards, vulnerabilities and risks *(continued)*

Hazard	Vulnerable sectors	Key risks
Landslides	Agriculture Forestry	<ul style="list-style-type: none"> • Damage to buildings, roads and infrastructure • Threat to human health and lives • Loss of agricultural and forest production
Soil erosion	Water Agriculture Tourism	<ul style="list-style-type: none"> • Increase of flood events • Erosion of fertile soils • Loss of agricultural production • Damage to buildings, roads and infrastructure
Rising temperature	Forestry	<ul style="list-style-type: none"> • Higher vulnerability of the forest for insect attacks and pathogens • Changing seasonality
	Biodiversity	<ul style="list-style-type: none"> • Species are forced to migrate to higher altitudes and change of species composition within ecosystems • Invasion of alien species • Outbreak of pests • Pressure on snow dependent species
	Agriculture	<ul style="list-style-type: none"> • Less water availability in spring / growing season
	Tourism	<ul style="list-style-type: none"> • Less snow for winter tourism and loss of income in remote mountain communities

CARPATHIAN MOUNTAINS

Analysis of adaptation policies for vulnerable sectors

Retezat and Tarcului Mountains

Global level

This section presents the main international conventions and policy documents dealing with adaptation to climate change applicable to the Carpathian region (with a focus on the most vulnerable sectors: water, agriculture, forestry, biodiversity, and tourism). Adaptation is an essential part of the UN Framework Convention on Climate Change (UNFCCC), which is ratified by all Carpathian countries. The Convention distinguishes between adaptation and mitigation of greenhouse gas (GHG) emissions to prevent temperatures rising beyond 2°C compared to pre-industrial levels. Adaptation aims to prevent risks and take advantage of opportunities created by

climate change. The UNFCCC obliges Parties to take measures to adapt to climate change nationally and in cooperation since climate change is beyond the point where only mitigation is sufficient. The Convention on Biological Diversity (1992) acknowledged the link between biodiversity conservation and climate change adaptation, which includes programmes on mountain biodiversity and forests. The main global financing mechanisms addressing adaptation to climate change include the Adaptation Fund, Special Climate Change Fund, Global Environment Facility and Green Climate Fund. There are also EU, bilateral, national and private funding schemes.



Buila-Vânturarița National Park, Romania

Regional and sub-regional levels

EU framework

The main EU policy document on adaptation is the Strategy on adaptation to climate change, which has three main objectives (European Commission, 2013a). The first is comprehensive adaptation by Member States, through National Adaptation Strategies aligned with the risk-assessment plans. The European Commission has elaborated guidelines for the national strategies of member states with six steps: involvement of competent authorities, risks assessment, identification of adaptation options, assessment of options considering political priorities and cost-benefit evaluations, implementation of the strategies, and regular monitoring (2013b). The EU also offers funding programmes, such as L'Instrument Financier pour l'Environnement (LIFE). The second objective of the EU Strategy on adaptation is to inform decision-making through EU-funded research programmes, like Horizon and the EU platform Climate-ADAPT. This platform contains information about climate change research, tools and policies. The third objective of the strategy is to integrate adaptation to climate change measures into key sectors of EU policy, such as agriculture and transport.

There are relevant EU policy documents in sectors that are important for adaptation in the Carpathians, including water, biodiversity, forests and tourism. For the water sector, there are river basin and flood risk management plans through the Water Framework and Floods directives. In October 2016, the European Council also adopted the Conclusions on Sustainable Water Management that address challenges related to land use and to climate change. The EU biodiversity

strategy (2011) recognizes that strengthening ecosystems is essential for both mitigation and increased resilience. The EU forest strategy (2013) also includes sustainable forest management measures for adaptation. In the tourism sector, the Communication from the Commission (2010) acknowledges the need for further action to make tourism more resilient to climatic changes. The EU Strategy for the Danube Region and its Action Plan recommend the development of a Climate Change Adaptation Strategy for the Danube Region, which has been adopted by the International Commission for the Protection of the Danube.

The International Commission for the Protection of the Danube River

The International Commission for the Protection of the Danube River is the implementing body of the Danube River Protection Convention (1994), which is ratified by all Carpathian countries except for Poland. The main objective of the Convention is to achieve the sustainable and equitable management of the Danube. The regional Strategy on Adaptation stresses the importance of the EU legal framework on water and floods for effective adaptation to climate change. It aims to support the second Danube River



Barania Góra, Silesian Beskid Mountains, Poland

Basin Management Plan, prescribed by EU law, to ensure that this plan fully integrates adaptation to climate change. The EU Strategy for the Danube region also addresses shared challenges relevant for climate change adaptation, such as environment risks and water management.

The Carpathian Convention

The Framework Convention on the Protection and Sustainable Development of the Carpathians (Carpathian Convention) aims to achieve the protection and the sustainable development of the Carpathians. It obliges the Parties to adopt appropriate measures, including integrated planning and management of ecosystems, land and water resources and cooperation on projects. A new Carpathian Convention Article on Climate Change

is under discussion among the Parties for possible adoption at the forthcoming 5th Meeting of the Conference of Parties to the Carpathian Convention October 2017 in Lillafüred, Hungary. The article calls the Parties to pursue climate change adaptation by promoting research and scientific cooperation, cross-sectoral integration, transnational cooperation, awareness raising, public participation and fostering local adaptation planning and implementation, especially in the most vulnerable areas and sectors.

The Carpathian Convention first addressed climate change in 2008 in water and integrated basin management. In 2011, it established the Working Group on Adaptation to Climate Change to collect information and data on climate change, promote regional cooperation on adaptation in the mountains and develop joint projects. Furthermore,

the Working Group has the mandate to assist the Parties with the implementation of the Strategic Agenda on Adaptation (2014). There are no sectoral strategies on adaptation to climate change in the Carpathian Convention. However, the Protocol on Sustainable Forest Management (2013) requires the Parties to integrate sustainable forest management in other policies, including climate change, and to adopt national measures to prevent floods and other extreme events specifically concerning adaptation.

CARPATCLIM, CARPIVIA and CarpathCC

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

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

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



COP Carpathian Convention

National policy frameworks for adaptation

The guiding national adaptation policies are the National Climate Adaptation Strategies. They indicate the objectives of adaptation in prioritized sectors to reduce the country's vulnerability to climate change. The National Climate Adaptation Action Plans outline the implementation of the Strategies and give indicators to measure progress. Another important document is the National Communication and to the UNFCCC (United Nations Framework Convention on Climate Change).

Most of the countries have not adopted mountain-specific laws, but they mainly refer to mountain agriculture within sectors (Czech Republic, Hungary and Slovakia). Mountain-specific laws are adopted in Romania and Ukraine; the other countries promote protection and development of mountain regions in their sectoral and mountain-related laws (Ruffini et al., 2006).

Czech Republic

The National Adaptation Strategy of the Czech Republic was adopted in 2015, in line with the EU Strategy on Adaptation and is coordinated by the Ministry of Environment (EEA, 2016d). The National Action Plan on Adaptation to Climate Change of 2017 addresses the following climate change impacts: droughts, extreme

weather, floods, flash floods and wild fires (EEA, 2016d). Besides the National Adaptation Strategy, there is also the Climate Protection Policy, which focuses on mitigation (Zámyslický, 2009). The State Environment Policy of the Czech Republic also provides climate adaptation measures (Ministry of the Environment of the Czech Republic, 2016). No policies or strategy documents that specifically address adaptation in mountain areas and the Carpathians could be found on the national level.

Hungary

The 2007 Climate Change Act is the framework for adaptation in Hungary, which prescribes a National Strategy and the adoption of National Climate Change Programs every two years (Lanfredi et al., 2013). Consequently, in 2008, a National Climate Change Strategy for the 2008-2025 period was revised (Hungarian Government, 2008). Mountain areas are recognized in this strategy as highly vulnerable to climate change; yet no concrete policies are adopted (Hungarian Government, 2008). The latest National Climate Change Strategy from 2013 gives an outlook up to 2050 (Geological and Geophysical Institute of Hungary). It contains the National Adaptation and the Low Carbon Development Strategies (EEA, 2016c). In 2009, the third National Environmental Action

Program was published, incorporating adaptation (EEA, 2016c). The National Biodiversity Strategy also addresses adaptation (Ministry of Agriculture Hungary, 2015). The National Framework Strategy on Sustainable Development (2012-2024) stresses sustainability through the protection of natural resources and heritage (Hungarian Government, 2013).

Poland

The National Adaptation Strategy of Poland was adopted in 2013 (Ministry of the Environment Poland, 2013). Climate change impacts on mountains are covered by their own chapter in the National Adaptation Strategy. However, more concrete action is required and there are no mountain specific laws in the national legislation of Poland. In Poland, there is no intention of preparing a national adaptation action plan (EEA, 2016a). However, the Ministry of Environment encourages regional and local authorities to prepare Action Plans (EEA, 2016a). Additionally, Poland adopted a National Action Plan on conservation and sustainable use of biodiversity for the 2015 – 2020 period (Council of Ministers Poland, 2015). A separate strategy paper for the agricultural sector was created in 2012 (Ministry of Agriculture and Rural Development Poland, 2012).

Principle documents	CZ	HU	PL	RO	SER	SK	UA
National Climate Change Adaptation Strategy	2015	2013	2013	2016	in progress	2014	–
National Climate Change Adaptation Action Plan	2017	2013	–	2016	in progress	sectoral action plans	–
National Communication to UNFCCC	2014	2014	2014	2013	2010	2014	2013



Sheep at Făgăraș Mountains, Romania

Romania

The Romanian Ministries have created an advisory body for climate change policies. The Romanian Ministry of Environment (2016a), through the World Bank project OPERA-Clima, developed the National Strategy on Climate Change and Growth based on low-carbon economy for the 2016-2020 period complemented with the National Action Plan on Climate Change (2016b). This also included assessments of adaptation for agriculture, rural development, forestry, water, urban areas and transport. The National Rural Development Program provides subsidies for adaptation measures (Ministry of Agriculture and Rural Development Romania, 2014). In addition, the OrientGate-Project proposed

adaptation measures for Romania's agriculture (Mateescu et al., 2014). The National Strategic Guidelines for the Sustainable Development of Less Favoured Mountain Areas (2014-2020) includes recommendations on sustainable development in the vulnerable Carpathian Mountains (Giurca, 2015). The Mountain Law (2004) establishes rules for the conservation of ecological balance and sustainable mountain development; these objectives are to be achieved by the National Agency of Mountain Areas.

Serbia

So far, Serbia has no national strategy on climate change, but it is mentioned as a significant risk in the National Strategy for Sustainable Development (2008) and the National Environmental Protection Program (2010). Serbia has few sector specific laws on climate change adaption, except for on forestry (Lanfredi et al., 2013). The 2015–2020 National Rural Development Program also indicates a need for studies on the potential agro-environmental measures for climate change mitigation and adaptation (UN, 2015). In the beginning of the EU accession process, progress in adaptation planning was made by harmonizing national legislation with EU requirements and establishing a monitoring system (GFA Consulting Group, 2016). Another step forward is an ongoing project funded by the EU and coordinated by the Ministry of Agriculture and Environmental Protection, which aims to prepare a national Climate Change Strategy and Action Plan (ibid.).

Slovakia

The National Adaptation Strategy of the Slovak Republic on Adverse Impacts of Climate Change of 2014 was elaborated in accordance with the EU 2014–2020 programming period (Ministry of Environment

of the Slovak Republic, 2016). Generally, adaptation measures for public health are prioritized (Ministry of Environment of the Slovak Republic, 2014). The next strategy will come in 2018 (ibid.). Action plans are mostly drafted and implemented by municipalities. On the national level, there are the National Action Plan for the energy sector and the Action Plan on GHG emissions reductions from 2012 (EEA, 2016e). The Action Plan on forestry is in development (ibid.). Other important national documents include the National Reform Program and the National Strategy for Risk Management (Chovancova et al., 2013; EEA, 2016e). The Act on Nature and Landscape Protection (2002) includes mountain specific aspects, yet the law does not specifically address mountainous areas.

Ukraine

The 2011 National Action Plan on Environmental Protection for the 2011–2015 period was developed to improve the environment through sustainable use of natural resources and conservation (Cabinet of Ministers of Ukraine, 2011). From 2011–2012, two versions of the National Adaptation Action Plan draft were developed, but not yet adopted by the Cabinet of Ministers of Ukraine (Shtets, 2015). The EU–Association Agreement signed in 2014 increased the harmonization with the EU legislation. The central focus was on support of core reforms, including environmental protection (Delegation of the European Union to Ukraine, 2016). The State Program on Water Sector Development from 2009–2020 promotes adaptation to climate change (OECD, 2017). Moreover, the Ukrainian Law on the Status of Mountains and Human Settlements that came into force in 1995 aims to protect vulnerable mountain populations by improving living conditions, ensuring social and economic development and providing technical and financial assistance for infrastructure development (Ruffini et al., 2006).



Pieniny



Ukraine

Adaptation measures addressing key hazards, vulnerabilities and risks

Gender and social inclusion policies

For efficient and comprehensive adaptation to climate change, all stakeholders must be engaged in the planning and implementation of adaptation measures, including women and other vulnerable groups. While gender equality is still a significant issue in the Carpathians, there are some examples of efforts that address women's concerns for climate change adaptation. Serbia addresses this issue with recommendations for the improvement of gender equality in the document Gender and Climate Change in the Republic of Serbia developed by the United Nations Development Program (Muric, 2015). In Romania, gender equality is also considered in the 2014-2020 National Rural Development Program by the Ministry of Labour, Family, Social Protection and Elderly (Ministry of Agriculture and Rural Development Romania, 2014). However, gender mainstreaming is generally not properly addressed in the Carpathian countries' policies and strategies. Addressing the needs of other vulnerable stakeholders, such as ethnic minorities and low-income groups is increasingly prioritized by national and sub-regional governments. For example, the Hungarian National Social Inclusion Strategy 2011–2020 provides a framework for implementing the social inclusion objectives defined



in the Government Programme focusing on extreme poverty, child poverty and social issues facing Roma people. Another example is the National Strategy for Roma in Slovakia has been developed by the Office of

the Plenipotentiary of the Government of the Slovak Republic and addresses the challenges associated with the social inclusion of Roma communities up to 2020.

Sectoral adaptation policies

Water

Flood Risk Management

The water sector in all the EU member countries in the Carpathians is regulated by the EU Water Framework and the Flood Risk Directives, which support an integrated approach of water management and regulation at the state level (EC, 2016a). Further flood measures provided in national documents are warning systems, infrastructural investments like dams or improvements of retention capacity. Furthermore, crosscutting measures from the agricultural sector reflect the importance of sustainable land use and agricultural practices to decrease water runoff from river basins (Ministry of Environment of the Slovak Republic, 2016; Božanić et al., 2010).

Sustainable use of water

Sustainable use of water is crucial for adaptation to the growing number of arid months. The National Adaptation Strategies of Romania, Hungary, Slovakia and Serbia recognize the importance of the effective use of water resources. Technological changes for revising water rights authorizations and regulations on the average rates of consumption are the intended means to reach this (Hungarian Government, 2008).

Drought Risk Management

Droughts and water shortages are expected in particular in the south of Hungary, Romania and Serbia (Werners et al., 2014). The Drought Management Centre for South-eastern Europe coordinates drought risk management tools and policies in the region, which includes Hungary, Romania and

Serbia from the Carpathian Region (DMCSEE, 2007). In addition, all countries have undertaken the National Capacity Self-Assessment for Global Environment Management, which helped determine their key capacity needs and implement the three Rio conventions (CBD, UNFCCC and the United Nations Convention to Combat Desertification (UNCCD)) (UNDP, 2017). The latter calls for the fulfilment of national reporting by each party, which the countries have accomplished to varying extents over successive reporting cycles. There are also ongoing projects, such as the DriDanube project which aims to increase the capacity of the Danube region to manage droughts. The UNCCD also demands National Action Programs, which are developed by Hungary, Poland, Romania, Slovakia and Ukraine. They serve

as a guide for combating desertification and land degradation. Poland has implemented the national System for Monitoring Agricultural Drought since 2007, and the Czech Republic has adopted the Integrated Drought Management System (Sadowski et al., 2013; CzechGlobe, 2015).

Sustainable land use and landslide prevention

Increase in peak precipitation events will increase the risk of erosion and landslides, especially in combination with unsustainable forestry at high altitudes (Werners et al., 2016). Soil erosion by wind and water is a pressing environmental problem in the Carpathians. Unsustainable agriculture, deforestation, overgrazing and forest fires are among the main causes (Letal & Smolova, 2009). Prevention

The JOINTISZA project (January 2017–June 2019)

Approved under the EU INTERREG Danube Transnational Programme, the project focuses on the interactions of two key aspects of water management – river basin management (RBM) and flood protection – while taking into account the relevant stakeholders who play a pivotal role in the Tisza RBM planning process. The main aim of the project is to further improve the integration of water management and flood risk prevention planning and actions for the next RBM planning cycle, in line with the relevant EU legislation.

Platform of Natural Water Retention Measures

The NRW initiative is a project of the Directorate General Environment for building knowledge and promoting best practices in natural water retention in Europe. The aim was to develop a European web-based knowledge base including technical, environmental, governance and implementation aspects of natural water retention measures. The safeguard and enhancement of the water storage potential of landscape, soils and aquifers restore ecosystems by using natural processes, supporting adaptation and hence reducing the vulnerability of water resources.

measures against soil erosion are addressed in the National Strategies, Environmental and Rural Programs and National Communications. Serbia and Romania explicitly refer to soil erosion in mountain areas, and suggest afforestation to address this issue (Bartholy et al., 2013; Ministry of Agriculture and Rural Development Romania, 2014).

In Poland, the protection of soil against erosion is determined by a national programme (Ministry of the Environment Poland, 2013). In 2015, Serbia introduced the Law on soil protection, which regulates the systematic monitoring of the quality of soil and its preservation (Serbian Government, 2015). The national strategies also aim for the prevention of constructions in landslide prone areas, crisis management in areas at risk, water regime adjustment to ensure vegetation cover in sensitive areas and afforestation measures to improve the surface leakage (Zámyslický et al., 2013; Hungarian Government, 2008; Ministry of Environment of the Slovak Republic, 2016) Ministry of Environment and Climate Change Romania, 2013).

Agriculture

The Carpathian region must address several climate change impacts in the agricultural sector. The change in precipitation and temperature rise will lead to pressure on field crops and can trigger increasing vulnerability to pests. In addition to higher temperatures, soil erosion and extreme weather contribute to productivity losses. All countries propose sustainable agriculture in their adaptation strategies to climate change. Sustainable resource

management also includes rational land use, which contributes to biodiversity preservation, sub-surface water storage and improved rainwater infiltration (Werners et al., 2016). The KEOP project (2012), for example, supported the restoration of grasslands in the Bükk region in Hungary by changing abandoned land into mowed grassland with fruit trees.

Afforestation of both abandoned and agricultural land for combating wind and water erosion, especially in steep zones, is considered in all analysed national documents except for Serbia. This is a crosscutting measure that affects the sectors of agriculture, forestry and biodiversity. To improve irrigation, the Carpathian countries promote better irrigation systems in their national strategies. Generally, technical adaptation measures in agriculture are important tools for policy makers in Poland, Romania, Hungary and the Czech Republic. The Agency for Restructuring and Modernizing Agriculture is responsible for undertaking investments in the agricultural sector and promoting energy efficient technologies in Poland (FAO, 2008).

Forestry

Forestry is important in the Carpathians, yet no country directly addresses climate change in its forestry legislation (Barcza et al., 2013). Although specific adaptation is scarce, significant adaptation is achieved indirectly. Measures prescribing sustainable forest management to maintain the functions of forest ecosystems are reflected in national strategies or programmes. In Ukraine, guidelines on sustainable forest management are prescribed in the National

Action Plan on Environmental Protection (Cabinet of Ministers of Ukraine, 2011). Reforestation is mentioned as an adaptation strategy in all countries. Serbia's Law on Forests prescribes that the forest users shall perform rehabilitation and reforestation measures on bare land or in areas affected by illegal clear cutting (Forest Law Serbia. Article 16.). In Romania, forest protection is guaranteed by the Forest Code, which also includes penalties and fines for illegal logging. The State Program Forests of Ukraine 2010–2015 includes afforestation measures, improvement of harvesting and use of timber (Bardarsja et al., 2013).

BioRegio Carpathians

Hungary, Slovakia, Romania, Serbia and Ukraine were part of this transnational project (2011–2013) for sustainable development and ecological connectivity in the region. The project included three pilot sites, which together covered five Carpathian countries. Each pilot site consisted of two bordering protected areas. A methodology was developed for integrated forest and wetland management. This project resulted in an enhanced management of the Carpathian protected areas and the maintenance of the biological and landscape diversity. Further, the development of a joint biodiversity geo-referenced web-based information system (CCIBIS) provided a solid information basis for the decision makers at the national and transnational levels.

However, only Poland's National Adaptation Strategy mentions the importance of monitoring the reaction of trees to climate change by observing phenological changes in tree cover, particularly in sensitive mountain areas (Ministry of the Environment Poland, 2013). Another example of adaptation is the installed monitoring and forecasting system for forest fires

in Slovakia or annual protection plans elaborated at the level of forest districts (EEA, 2016e; Mateescu et al., 2014). Further, the EU-member states Slovakia, Poland, Hungary, Romania and the Czech Republic take part in the LIFE+ project FUTMON (Futmon, 2016), which provides data on climate change and the reactions of forest ecosystems.

Biodiversity

Healthy ecosystems are more resilient to climate change and can therefore continue providing ecosystem services like water provisioning, carbon sequestration and preventing floods. Ecosystem and biodiversity management is hence important

TRANSGREEN (January 2017–June 2019)

TRANSGREEN (Integrated transport and green infrastructure planning in the Danube-Carpathian region for the benefit of people and nature) aims to contribute to safer and environmentally-friendly road and rail networks in mountainous regions of the Danube Basin with a special focus on the Carpathian Mountains. It will do so by improving planning frameworks and developing concrete environmentally-friendly and safe road and rail transport solutions taking into account elements of Green Infrastructure, in particular ecological corridors. Innovative pilot actions (in Beskydy (CZ-SK), Miskolc-Kosice-Uzhgorod (HU-SK-UA), Tirgu Mures-Iasi and Arad (Radna)-Deva (RO)) will focus on ecological corridors crossed by EU TEN-T road and rail projects in the Carpathians. An interdisciplinary partnership comprised of planners, economists, engineers, and ecologists will integrate and apply their specific knowledge across the region and cooperate on developing Guidelines on integrated transport infrastructure planning, construction, management and monitoring, taking into account aspects of road safety and biodiversity conservation.



for adaptation. Protection of endangered habitats and management plans for natural habitats are prescribed by the EU Habitat Directive for the EU member states. Networks of protected areas and nature conservation as well as protected biotopes are regulated in the National Strategies (Ministry of Agriculture Hungary, 2015; Ministry of Environment of the Slovak Republic, 2016). Concrete measures are also taken on the national level. For example, Poland is creating ecological corridors under its “Programme of Conservation and Sustainable use of Biodiversity along with Action plan for the 2015–2020 period” (Council of Ministers Poland, 2015).

The Carpathian forests include the largest area of virgin forest in Europe, which provides high biodiversity value and habitats for many endangered species (Meyer & Papp, 2014a). To prevent the extinction of these species, national adaptation measures include: the restoration of natural habitats, national monitoring systems of endangered species, and a priority list of habitats and species considered sensitive to climate change (Ministry of the Environment Poland, 2013; Božanić et al., 2010; Ministry of Environment and Climate Change Romania, 2013; Hungarian Government, 2008)

Tourism

Impacts of climate change on tourism can be twofold: on the one hand, rising temperatures will diminish the days with snow cover in winter, so the possibilities of winter sports in the Carpathian Mountains will become more limited. On the other hand, countries in the Danube-Carpathian region might also benefit from people wanting to escape the heat in lowland areas (Central European University, 2008). According to the World Tourism Organization, the Carpathians have the potential to

become one of the three most attractive European destinations for nature and culture-based tourism (Niewiadomski, 2017). Most countries already implement sustainable tourism measures. To adapt winter tourism to global warming, Romania and Slovakia emphasize four season green mountain resorts and diversification (Ministry of

Environment and Climate Change Romania, 2013, Ministry of Environment of the Slovak Republic, 2016). For maintaining Skiing on higher altitudes, Slovakia has suggested increased production of artificial snow as relevant counteracting adaptation measures (Ministry of Environment of the Slovak Republic, 2016; Chovancova et al., 2013).



Travel green – with zero emissions in the Mara-Cosău-Creasta Ccoşului eco-destination

The primary goal of the project is to reduce the CO₂ generated by tourism activities. The Mara-Cosău-Creasta Ccoşului eco-destination serves as a model area for sustainable development to reach this objective. The development of a specific cycling offer for tourists shall increase the attractiveness of the region for bikers and simultaneously stimulate sustainable mobility. The six new bicycle trails connect the villages along the Cosău valley where local guesthouses equipped and prepared for cycling welcome the tourists. Furthermore, a GPS driven tourism guide developed for mobiles and tablets, a web site and leaflets with maps secure attraction. In addition, a partnership of 25 guesthouses demonstrates efficient practices to reduce their CO₂ emissions, while facilitating the access to the market for local producers.

Institutions and Stakeholders

On the supranational level, the EU has major influence on climate adaptation policies by requiring the integration of EU-laws into national laws and by funding programmes. Serbia has started the EU accession process, while Ukraine has an association agreement with the EU (EC, 2016b; EC, 2016c). The South-East Europe Transnational Cooperation Programme includes all Carpathian countries (incl. non-EU members). Other important EU programmes are ESPON, HORIZON 2020 and LIFE, which support environmental, nature conservation and climate action projects. The EU funding for Serbia comes from the Pre-Accession Assistance and for Ukraine from the European Neighbourhood Policy funding. Third party funding is especially important for Ukraine and Serbia, relative to their state budget (Lanfredi et al., 2013). Other international organizations also finance climate adaptation. The World Bank has done important work in Romania, supporting with major technical assistance in the development of the current National Climate Adaptation Strategy and Action Plan. Poland, Slovakia, Czech Republic, Romania and Hungary are beneficiary countries of the EEA and Norway Grants, which are funds provided by Iceland, Liechtenstein and Norway to promote sustainable development in Central and Southern Europe (EEA Grants & Norway Grants, 2017). S4C Science for the Carpathians is also an important regional platform for scientists working on the region. It connects scientists in Central Europe, defines research priorities and enhances collaboration with partners from outside the Carpathians.



On the local level, there is a European initiative called the Covenant of Mayors, which is a platform that invites local authorities to commit to developing Sustainable Energy and Climate Action Plans for 2030 and to implement local climate change mitigation and adaptation (Covenant of Mayors for Climate & Energy, 2016). This platform allows local authorities to contribute to the EU's climate policy (ibid.). All seven countries have at least one participating local authority and most countries have several (Covenant of Mayors for Climate & Energy, 2017). Furthermore, the Local Agenda 21, an initiative by the United Nations, supports local climate change projects (UN, 1992).

CARPATHIAN MOUNTAINS

Gap analysis

Zakarpattia, Ukraine

This chapter presents gaps in adaptation measures in the Carpathians. Adaptation policies must address the risks and vulnerabilities presented in chapter 2. The success of climate change adaptation depends on whether the most pressing climate change related risks are addressed in existing policies. The

EU Adaptation Strategy (2013) gives a framework and guidelines for coherent and coordinated regional adaptation. Strategies should also include tailor-made measures for the specific challenges of the Carpathians. The Carpathian countries, in the framework of the Carpathian Convention, are

already following a coordinated approach, which takes explicitly into account the sensitivity of mountains areas. This should be further enhanced. However, also on the national level more awareness and action on climate adaptation is needed for mountainous areas.



Domogled-Valea Cernei National Park, Romania

The National Adaptation Strategy documents generally address the key hazards in the selected sectors of water, agriculture, forestry, biodiversity and tourism. However, adaptation strategies and policies remain vague. More concrete actions are needed to reach the strategic targets. Mountainous regions are particularly vulnerable to climate change and concrete measures rarely address these regions and their special needs directly. Notable exceptions in the national legislations include the Mountain Law (2004) of Romania and the Ukrainian Law on the Status of Mountains and Human Settlements (Ruffini et al., 2006). Compared to the detailed programmes and strategy papers of EU-countries on climate change issues, Ukraine and Serbia in particular, have less developed strategies. These countries also lack data and analyses on how climate change affects distinct parts of their territory, industries and policy sectors. Both countries need political and financial support to improve adaptation. However, a challenge is that they receive less funding and the GDP of Serbia and Ukraine is lower than in the other Carpathian countries (World Bank, 2017). Further, partly due to the insecure political situation in Ukraine, certain climate adaptation actions have been delayed (Shtets, 2015).

EU-countries also benefit more from EU funded projects. Especially the European LIFE fund offers financial support for environment, nature conservation and climate action projects. For example, the project Forest-Alp as part of NATURA 2000 for sub-alpine and alpine habitats in Romania

helped to prepare the specification of Romanian NATURA 2000 sites for forests, subalpine and alpine habitats (UN, 2012). However, also non-EU member states receive funding from the EU through the European Neighbourhood Policy Instrument funding and the Pre-Accession Assistance. Through these funds, also Ukraine and Serbia can participate in programmes like the INTERREG Danube Transnational Programme (EU, 2009). However, the interim evaluation of the EU Horizon 2020 funding programme, which also finances projects on climate change issues, shows that Eastern European countries have a lower application rate and a lower success-rate on approved projects compared to Western EU countries (7–8% against 12–13%) (EU, 2016).

Flooding

Early warning systems for floods require monitoring and forecasts to reduce risks. To reduce climate hazards, it will be important to improve these systems. Generally, through the EU Flood Risk Directive (2007) a framework already exists for these measures. In addition, flood-risk maps need to be implemented. For example, Ukraine did not yet regulate flood risk mapping on the national level. Serbia is in the process of producing flood risk maps in a programme supported by the World Bank (GFDRR, 2017). In the existing strategies and policies, there is often a lack of concrete commitment to infrastructural measures. Yet, neglecting these initiatives can lead to much higher costs such as the loss of agricultural production and damage to infrastructure. Improving the capacity of ecosystems to prevent flood damage is also essential in addition to traditional infrastructure. For example, the preservation of Divici Pojejena Wetland in the Iron Gates National Park in Romania improves water storage through natural resources (Arany et al., 2013; Salzmann et al., 2016).

Wildfires

Wildfires are an increasing threat to human lives and ecosystem services. As a further consequence, the risk of other hazards like landslides or soil erosion rises, after wildfires occurred. Many policy sectors are affected by wildfires, including agriculture, forestry, biodiversity and tourism. However, wildfires are generally addressed in the forestry sector. General measures for protecting forests from wildfires are usually included in the national legislation and are as

well considered in the National Adaptation Strategies and UNFCCC Communications. In the National Strategy of Ukraine, however, there is no mention of dangers from wildfires. Important fire protection measures in the Carpathians are monitoring and forecasting systems for wildfires. Based on this information, fire protection plans should be elaborated. Currently, they are present to some extent, but do not yet cover the whole region. Increased cooperation between sectoral authorities is important to effectively address the rising risk of wildfires.





Relict pine forest in the Pieniny

Water scarcity, droughts

Water scarcity and droughts are among the key hazards from climate change in the Carpathians. There are many examples of policies addressing these issues. For example, Romania's Action Plan aims to invest further in rehabilitation and modernization of irrigation and drainage infrastructure (Ministry of Environment, Waters and Forests Romania and World Bank, 2016b). Water saving irrigation technology is only addressed in half of the Carpathian countries. It is essential to improve forecasting measures using modern technological innovations, such as Remote Sensing. Drought vulnerability maps are already developed in the Carpathian area. They improve adaptive capacity to water scarcity and droughts. Research on climate change adapted crops and cultivation practices should be increased due to the vulnerability of agriculture to droughts. Climate adaptive forest management measures are also essential and should be further promoted in the Carpathians. Droughts and water scarcity also have significant impacts on biodiversity and natural conservation. For example, installing monitoring systems to control endangered species is a useful adaptation measure.

Landslides

Due to an increase in extreme precipitation events, landslides could become more frequent. Montane and subalpine forests are important for protecting people and infrastructure from the impacts of natural hazards by preventing erosion and landslides (Werners, 2014a). Therefore, afforestation is an important cross-sectoral measure. Every Carpathian country recognized the importance of this measure in one or several of their strategy documents. However, a lack of coordination between ministries can lead to ineffective implementation. Landslide

and integrated hazard risk mapping, could also be an appropriate instrument for the Carpathians. Until now, only Hungary and the Czech Republic have risk sensitive regulations in land zoning (HFA 2015). However, about half of the Carpathians include land zone planning measures to prevent landslides in their national strategies. The Hyogo Framework for Action National Progress Reports also show that only Poland, Hungary, Czech Republic and Slovakia undertake technical construction to prevent landslides. This is a gap, which should be addressed to protect people and property.

Soil erosion

Soil erosion is a pressing environmental problem in the Carpathians. An increase in peak precipitation events due to climate change, in combination with unsustainable agriculture and forestry can reinforce erosion. Economic losses caused by increased erosion requires further action (Hreško et al., 2016). Soil monitoring is well addressed by all countries. However, land protection is poorly addressed by legislation. A crosscutting measure addressing this issue is afforestation, which reduces wind and water erosion. Generally, afforestation is addressed by all countries. However, the protection of heterogeneous landscapes is not sufficiently addressed. Strengthening protected areas is one way to preserve these natural resources.

Reduced snow cover

Rising temperatures will reduce snow cover which will affect the tourism industry, ecosystems and the hydrology of the region. Especially the skiing industry in lower altitudes will suffer economic losses. The Carpathians might also benefit from shifting tourism flows to the mountains. National strategies addressing winter tourism are insufficiently forward looking.

However, Slovakia for example, considers the transfer of skiing infrastructure to higher altitudes and increased production of artificial snow as relevant measures (Ministry of Environment of the Slovak Republic, 2016; Chovancova et al., 2013). Activities alternative to winter sports in mountains should be developed as a possible adaptation measure. For example, where eco-certificates are developed to further ecotourism in Romania and the Czech Republic. In addition, marketing could be improved to attract more tourists to the Carpathians and to facilitate diversification in targeted mountain areas.

Acronyms

CARPATCLIM	Climate of the Carpathian Region project
CarpathCC	Climate change in the Carpathian Region project
CARPIVIA	Carpathian Integrated Assessment of Vulnerability to Climate Change and Ecosystem-based Adaptation Measures project
CCIBIS	Carpathian Countries Integrated Biodiversity Information System
Climate-ADAPT	European Climate Adaptation Platform
CZ	Czech Republic
ESPON	European Spatial Planning Observation Network
EU	European Union
EURO-CORDEX	Coordinated Downscaling Experiment – European Domain
GDP	Gross domestic product
GHG	Greenhouse Gas
GPS	Global Positioning System
Horizon 2020	EU Research and Innovation programme
HU	Hungary
ICPDR	International Commission for the Protection of the Danube River
IPCC	Intergovernmental Panel for Climate Change
LIFE	EU's Funding Programme for the Environment and Climate Action
Natura 2000	network of core breeding and resting sites for rare and threatened species
NRWM	Platform of Natural Water Retention Measures
PL	Poland
RBM	river basin management
RCP	Representative Concentration Pathways
RO	Romania
SER	Serbia
SK	Slovak Republic
UA	Ukraine
UN Environment	United Nations Environment Programme
UNCCD	United Nations Convention to Combat Desertification
UNFCCC	United Nations Framework Convention on Climate Change

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