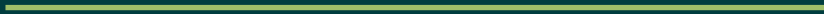


# S4C Research Agenda 2022–2030



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# S4C Research Agenda 2022–2030

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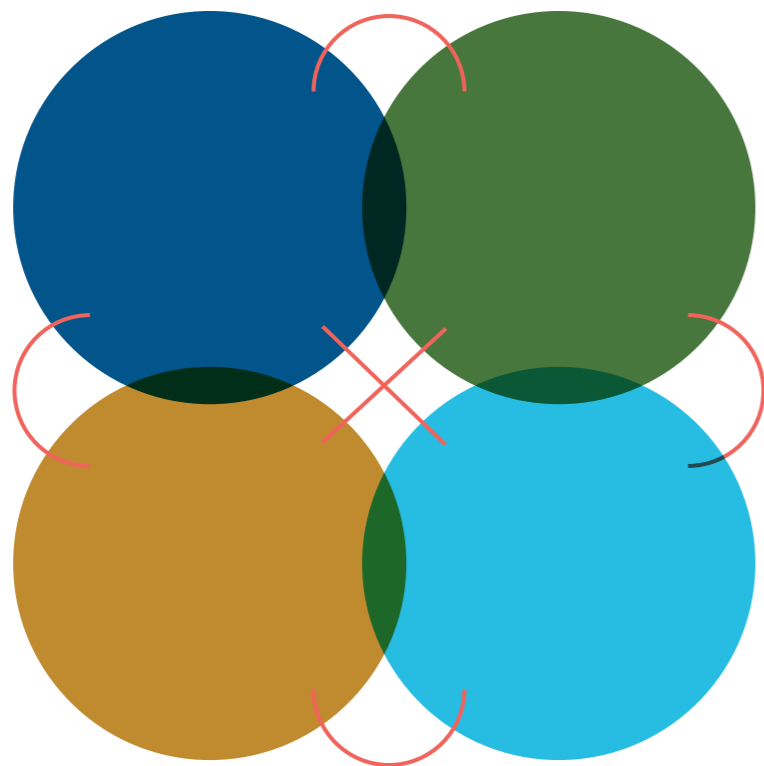


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<http://carpathianscience.org/>





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# Introduction – (re) shaping the Common Vision on the future of Carpathian Research



The Science for the Carpathians (S4C) network, established in 2008, aims at defining research priorities for the Carpathian region and linking research, policy, and practice (Kozak et al. 2011). The S4C Conference, Forum Carpaticum, has been organised on a biennial basis as a meeting point among the scientists, as well as practitioners and policy-makers, devoted to integration of knowledge across sectors, to address challenges of the Carpathian region.

The *1st Forum Carpaticum (2010, Kraków, Poland)*, was dedicated to the “Integration of nature and society towards sustainability” and identified the need for better information on data generation, availability, and accessibility in the Carpathians region. The conference programme of the *2nd FC Forum Carpaticum (2012, Stará Lesná, Slovakia)* discussed the data-knowledge-action circle in three overarching and overlapping themes: 1) Abiotic Environment, 2) Biodiversity and ecosystems and 3) Human Dimensions. The *3rd Forum Carpaticum (2014, Lviv, Ukraine)* were related, but not limited, to the policy priorities of the Europe 2020 Strategy and the Horizon 2020 Programme, focusing on major challenges affecting the Carpathian ecoregion.

Since its formation, but particularly in the last several years, the S4C made efforts to strengthen interdisciplinary and transdisciplinary research and promote these approaches among its members and young scientists from the Carpathian countries. At the *4th Forum Carpaticum (2016, Bucharest, Romania)* an emerging theme in the Carpathian area was the education for sustainability, debated in workshops as well as during oral and poster presentations. Most sessions and keynote speeches of the *5th Forum Carpaticum (2018,*

*Eger, Hungary*) addressed interdisciplinary and intersectoral linkages, among others, such topic as climate change vulnerability assessment, and adaptation, potential of social innovation in the Carpathian area, green energy innovations, workshop on education for sustainable development (Mázsa, 2018). The S4C Steering and Executive committee members are working on strengthening exchange of knowledge and collaboration among the S4C scientists, practitioners and policy-makers engaged in the Carpathians.

The S4C has since its establishment maintained a close relationship with the Framework Convention on the Protection and Sustainable Development of the Carpathians (Carpathian Convention) – a Multilateral Environmental Agreement, adopted by the seven Carpathian countries (Czech Republic, Hungary, Poland, Romania, Serbia, Slovak Republic, Ukraine) in May 2003 in Kyiv, Ukraine. The Convention, which entered into force in 2006, constitutes the first regional agreement addressing sustainable development of the Carpathians region at the policy level. The S4C provides regular inputs, based on the results of the Forum Carpathicum conferences, to the Convention Secretariat and the Convention Conference of the Parties, the main decision-making body of the Convention.

Close collaboration among the Carpathian Convention and the S4C network continues – for example, through co-organised events. Joint discussions focused on identifying: 1) urgent knowledge gaps in the fields addressed by the Carpathian Convention (2003), as well as the related to the Sustainable Development Goals (UN 2015), including conservation of biodiversity, education for sustainable development, sustainable tourism and climate change; 2) important interdisciplinary areas and research questions, which can be addressed by S4C and 3) concrete ways and opportunities for scientists to cooperate with the Convention Secretariat and parties, in order to support the implementation of the Convention.

During the recent *6th Forum Carpathicum*, “Linking the Environmental, Political and Societal Aspects for Carpathian Sustainability”, which took place *virtually in June 2021* (Cudlin and Pich, 2021), a Plenary has been devoted to discussion about how to enhance the role of Carpathian scientists and transdisciplinary approaches for sustainable development of the region. Furthermore, a broad participatory approach, initiated by the S4C, resulted in collecting recommendations from all conference participants for the Research Agenda for the Carpathians, and for the implementation of the Carpathian Convention (Zawiejska and Mitrofanenko 2021).

## In the 2020–2030 period we envision:

- **Stronger participation of S4C in Carpathian Convention activities**, and closer collaboration between S4C and the Convention Secretariat, Focal Points, Working Groups (WG) and other partners. Our vision in this respect includes:
  - S4C colleagues often represented at the WG and Carpathian Convention Implementation committee (CCIC) meetings,
  - The S4C Executive Board and Steering Committee remain open to communication and collaboration with convention Parties and Partners,
  - Important S4C updates, relevant for policy and practice, are communicated to the Convention Secretariat, and published on the Convention website,
  - Carpathian Convention Focal Points are invited to the relevant scientific events on the national and regional level.
- **Stronger collaborations with other mountain research networks**, such as the Scientific Network for the Caucasus Mountain Region (SNC-mt)<sup>1</sup>, the International Scientific Committee on Research in the Alps (ISCAR), and the Mountain Research Initiative (MRI). In 2021 S4C and SNC-mt signed an MoU to strengthen cross-regional collaboration. Our vision in this respect includes:
  - Exchange of information and knowledge,
  - Supporting cooperation between individual network members, cooperation during regional conferences,
  - Development, financing, and implementation of joint activities, aimed at building research capacities and fostering dialogue between research, policy and practice, in order to link research to the needs of sustainable development and environmental protection of the both ecoregions,
  - Cross-regional exchange and learning, addressing socio-ecological challenges and facilitating sustainability transformations of mountainous regions.
- Intensifying **efforts to involve younger and early career scientists in the S4C**, as well as providing them opportunities for training and exchange. Our vision in this respect includes:

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<sup>1</sup> [www.caucasus-mt.net](http://www.caucasus-mt.net) (last accessed 2022.02.07)

- Further supporting participation of young and early-career researchers from the Carpathian countries in the Forum Carpaticum conferences,
- Organising regular training and exchange opportunities for young and early-career researchers from the Carpathian countries, such as summer and winter schools, in order to create a better understanding of the complex challenges faced by the Carpathian region, and jointly learn how inter- and transdisciplinary approaches can be applied to address these challenges effectively.

## Aims for the S4C Research Agenda 2022–2030:

In the next chapters we present a number of topics, which the S4C research community finds most critical and fundamental for supporting sustainable development of the Carpathian region. For each topic, we provide a brief introduction, as well as recommended topics and research questions to guide research.

We envision the given **S4C Research Agenda 2022–2030** as a fluid document in development – S4C members and peers will be encouraged to revisit and revise it to maintain its relevance for the region.



Interested scientists, practitioners, policy-makers are welcome to **Join us!** by becoming a member of the S4C Network, or following our activities: <http://carpathianscience.org/>

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# S4C Research Agenda 2022–2030

## Topics and Research questions guiding inter- and transdisciplinary collaboration for sustainable development of the Carpathian Region

### 1 Climate Change

Pavel  
Cudlín



There are currently significant relatively rapid phenomena and processes on Earth, which we include under the term “climate change”. Its most pronounced manifestation is global warming (Rignot et al, 2019). The cause of current global warming and related phenomena is the intensification of the greenhouse effect of the atmosphere due to the increase in the concentration of greenhouse gases (Powell et al., 2017). The increase in the amount of greenhouse gases in the atmosphere occurs mainly through the combustion of fossil fuels (Quéré et al., 2018). Current climate change cannot be explained by natural climate variability or changes in natural climate-forming factors (Ganopolski et al., 2016). Climate change is a global problem that not only affects us, but we also have a stake in it. The possibilities of its mitigation or adaptation are professionally developed but their implementation significantly depends on the decisions of national governments (Murphy and Ravishankara, 2018).

According to a representative set of regional climate models (EURO-CORDEX), the intensity of the observed manifestations of ongoing climate change will increase in the coming decades. According to the most likely scenario, greenhouse gas emissions in Central Europe will result in warming by an average of 2 °C by the middle of the century, compared to the average of 1981–2010. Annual precipitation totals will increase only slightly or stagnate. A slight increase in precipitation is expected in the winter months, but in the lower and middle altitudes it will mostly be rainy. In the summer, on the other hand, the models expect a decrease in the amount of precipitation. Combined with higher temperatures, this will lead, among other things, to an increase in the evaporation of water available in the landscape, and thus to a significant risk of more frequent and prolonged drought episodes. Particularly southern locations will be affected, with significant risks in the form of serious deterioration in agricultural production and forest growth conditions (EEA, 2020).

## Recommended topics

- Selection of a sufficiently wide range of regional climate models for individual areas of the Carpathians. Additional downscaling of selected climate models for regional studies
- Use of envelop models to estimate the impact of changing climatic conditions on major ecosystems and ecosystem service providers
- Social aspects of climate change mitigation measures
- Resilience of ecosystem services and land use practices to climate change.

## Recommended research questions

- Which of the climate change mitigation measures are relevant and socially acceptable in the Carpathian region?
- Which groups of ecosystem services are the most affected by the impacts of climate change in the Carpathian region and what measures can be implemented to prevent their further degradation?
- Are there any practices (forest management, farming methods) in the Carpathian region that are resilient to climate change?
- What are most appropriate climate change mitigation and adaptation measures in the Carpathians, considering their complexity and mutual positive and negative effects in terms of expected future developments?.

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-



## 2 Water resources and management



Bartłomiej  
Wyżga  
Joanna  
Zawiejska

While numerous studies explored the pollution of the environment with microplastic, the pollution of riverine environment with macroplastic debris has only recently been recognized and research allowing for identification of mechanisms and rates of macroplastic storage, transport, and redeposition in rivers is required (Liro et al., 2020). In the 20th century, valleys of Polish Carpathian rivers experienced considerable expansion of floodplain forest and the change has important impacts on riverine ecosystems and flood hazard (Hajdukiewicz and Wyżga, 2020) – however, recent trends of forest development may differ among Carpathian countries. Trees fallen to river channels were recognized



Fluvially transported plastic debris



Near-natural reach of a large Carpathian river



Regulated Dřevnice river, West Carpathians, Czech Republic

to beneficially influence ecological processes in rivers, but mobility of in-channel wood during floods may pose hazard to property and infrastructure on valley floors. Sustainable management of in-channel wood requires knowledge of its mobility, which can differ considerably between mountain channels of different size (Mikuś et al., 2016). The ongoing climate change may variously affect flow characteristics of Carpathian rivers, such as flow



Riparian forest developed along a large Carpathian river (Czarny Dunajec, Poland)

amount, seasonality of extremes and temperature regime (Kędra, 2020), depending on river location in the Carpathian arc. Conventional engineering management of mountain streams was shown to exert negative impacts on all dimensions of sediment connectivity and, thus, on hydromorphological stream quality. Therefore, there is a need to find and apply more environment-friendly approaches to the management of mountain streams (Galia et al., 2021). The onset of restoration projects in Carpathian streams and rivers raises the question of suitability and effectiveness of applied restoration measures. Scientific monitoring of river restoration projects is thus required to help the choice and promote a wider use of innovative, cost-effective restoration measures aimed to improve the functioning of degraded mountain ecosystems (Wyzga et al., 2021).

## Recommended topics

- Pollution of mountain watercourses with micro- and macroplastic, including storage and redeposition of plastic in the river sediments.
- Recent trends of development/decline of riparian forests along mountain rivers in Carpathian countries and their impact on changes of the quality of riverine and riparian ecosystems and flood hazard

- Assessment of the mobility of in-channel wood in mountain watercourses narrower and wider than the height of riparian trees with use of a variety of monitoring techniques
- Impacts of climate changes on the amount and variability of river flow, including the frequency and seasonality of extreme events (floods and droughts), and thermal regime of river waters
- Changes in sediment connectivity in Carpathian rivers resulting from various engineering measures (channelization structures, dams, check-dams) and channel incision
- Evaluation of immediate and long-term effects of river restoration projects

## Recommended research questions

- What are the morphological features of mountain rivers that promote the entrapment and storage of plastic debris and where can the debris be preferentially transported downstream?
- What is the spatial distribution of plastic pollution in Carpathian rivers?
- What are the drivers of recent changes in the occurrence of riparian forests in the valleys of Carpathian rivers?
- How does the mobility of in-channel wood differ between mountain watercourses of different sizes and how do these differences affect flood hazard in the valleys?
- How do river restoration projects modify abiotic and biotic characteristics of degraded mountain watercourses during the time span of these projects and in the long term?

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## 3 Natural hazards and risks



Paweł  
Kroh

Mountainous areas are predestined for natural hazards. Relief energy and high intensity of natural processes create risks for people residing in mountainous areas, potentially more serious than risks posed to populations living elsewhere. Climate change and increasing intensity of extreme events means that risks have to be taken into account for social development in the Carpathians. The most important point of view is that all such phenomena are natural processes and they become ‘risks’ only from a human point of view. Respect for nature and understanding of its functioning is the most effective way to reduce future losses.

### Recommended topics

- ‘Living with hazards’ - development of society with respect to natural processes
- Susceptibility and risk assessment for main natural hazards in the Carpathians - landslides, floods, flash floods, local droughts, strong winds, avalanches
- Natural hazard’s impact on safety
- Implementation of results on natural hazard research in spatial planning
- Prediction of natural hazard occurrence and rates in the climate change context, for example:
  - precipitation change vs landsliding susceptibility
  - snow cover and rainfall vs flash floods
  - local droughts vs susceptibility
  - transboundary research and risk management: integration of natural hazards research and risk management between neighbouring countries and regions, especially when natural systems (e.g. catchment area) are shared by two countries



Slide around the stream,  
Western Carpathians,  
Czech Republic

## Recommended research questions

- How to develop society and its infrastructure in a sustainable way, with respect for natural resources and processes?
- How will climate change affect the intensity of natural processes and susceptibility for natural hazards?

## 4 Land use and land cover change



Dominik  
Kaim

Dominant land use processes observed in the Carpathian region are land abandonment leading to forest cover increase (Kolecka et al., 2017, Pazur et al., 2014, Săvulescu et al., 2019) and settlement development (Kaim 2017, Pazur, Bolliger, 2017) - that leads to farmland decrease. Critical drivers for land use change include: climate change, demographic processes, policy and institutional interventions (e.g. Common Agricultural Policy, Biodiversity Strategy 2030 etc.). Settlement pressure and sprawl in the region results in strong impacts on biodiversity and ecosystems (e.g. movement barriers, light pollution, noise pollution, human-wildlife interactions). At the same time, traditional land management approaches have been preserved throughout the Carpathian region, including in some of its lesser-known, peripheral areas (for example, at the junction of the Carpathian and Pannonian regions). Protection of these peripheral areas, which often form a buffer between the intensively used agrarian landscape and the forested piedmont and mountain landscapes.

## Recommended topics

- Multi-disciplinary research of rural areas especially in context of their depopulation, including measures to stop this trend.
- Research to facilitate ecological restoration of Carpathians grasslands.
- Understanding, mapping and supporting traditional land management approaches in the Carpathian region
- Land abandonment and its consequences in the Carpathians
- Long-term land use legacies in the region
- Scenarios of the future land use changes in regard to demography and climate change in the region.



Cottage colony,  
Western Carpathians,  
Czech Republic



Land use in the Polish Carpathians

## Recommended research questions

- How will land use change in the Carpathians affect biodiversity and other ecosystem services in future?
- How will the land use be affected in future by the critical drivers, which are: climate change, demographic processes, policy and institutional interventions (Common Agricultural Policy, Biodiversity Strategy 2030 etc.)?

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## 5 Integrated landscape management and governance for better regional development policy



Mariana  
Melnykovich

Magdalena  
Kubal-Czerwińska

Sustainable landscape governance should be based on the following principles: inclusive decision-making in the landscape, culture of collaboration in the landscape, coordination across landscape sectors, levels and actors, sustainable landscape thinking and action based on nature-based approaches to land use and natural resource management. Based on such principles, land-use planning and management practices can limit the degradation of water, forests, grasslands and soils, and promote their restoration while conserving biodiversity, thus contributing to sustainable landscapes. The loss of traditional inherited knowledge in land-use governance and management is gaining importance in the context of increasing rates of rural depopulation in the Carpathians (Molnar and Berkes, 2018; Smaliychuk et al., 2016). For example, agricultural land is being abandoned due to the continuous decline of rural population, increasing urbanisation, outmigration, marginalisation, and dependency on the external economy. The trend of a gradual increase of abandoned agricultural land will likely continue in the next decade (EC, 2020). Therefore, novel approaches and governance models, often based on traditional landscape management approaches, are receiving increased attention in policy debates and scientific research (e.g. social innovation to promote sustainable landscape governance).

It is critical to understand possible pathways and enabling factors for the revitalisation of inherited landscape governance (e.g., farming practices) in order to preserve them. Finding new mechanisms for the governance and use of agricultural land, e.g. based on traditional farming approaches, is crucial (Molnar and Berkes, 2018). A holistic consideration of the influence of energy flows on ecosystem services, both within and outside Carpathian markets, could help identify ways towards decarbonization, while simultaneously maximising the benefits that people derive from nature. It is important not only to preserve traditional knowledge, but also, in the current socio-economic conditions, to apply novel governance mechanisms by integrating traditional approaches into new agricultural practices (see Spacek et al., 2020).

### Recommended topics

- Green infrastructure planning
- Sustainable green energy provision in the Carpathians (e.g. action research with relevant stakeholders involved, including NGOs, Universities, local authorities), including formation of citizen energy communities
- Shift to Renewable Energy (such as thermal solar facilities on the roof of kindergartens, schools, etc)
- Adopting a broader approach to protecting the few remaining valleys in the Carpathians where natural processes and dynamics are operating at truly landscape scales
- Building a ground for creation of common policy, enforcement of the law in terms of voluntary and obligatory forest certification requirements
- Participatory natural resource governance, including on the transboundary level

### Recommended research questions

- How can the interaction of actors and their networks foster knowledge co-production for the revitalisation of traditional farming, and thus the reconfiguration of social practices towards sustainability transformation?
- How could smart resource management help stakeholders to more effectively deliver and adapt concepts of bio- and circular economy as well as less waste in environmental, economic, and social challenges of the Carpathian region?

- How is it possible to design a common, united and holistic development policy to change the Carpathians into an ecologically efficient region?
- How can circular business models in the public and private sector be introduced and evaluated in common integrated resource management and regional development policy?
- How can local initiatives of environmental, economic, and social nature be designed to use and reuse Carpathians' resources?
- Which solutions gained broadly from bio and circular economy might be introduced into integrated resource management policies in the Carpathians, and how?
- How might traditional ecological knowledge be encouraged and in some cases adapted for present changing environmental conditions?

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## 6 Forests, their management and governance



William S.  
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Forest ecosystems in the Carpathians will continue to change into the future as compounded stresses from climate disruption, alteration of disturbance regimes, invasive species, land use pressures, and other factors increase. With changes in ecosystem dynamics will come shifts in the mix of ecosystem goods and services those forests provide (Kruhlov et al. 2018, Thom et al. 2019). Foresters, scientists, and policy makers alike are challenged to integrate knowledge from multiple disciplines in addressing questions



Beech forest  
with *Lunaria rediviva*  
in Western Carpathians



Natural forest  
in Western Carpathians

of climate change. Our research agenda will address the multiple ecological, social, and economic dimensions of global change as it pertains to the forest sector.

Forests in the Carpathians, as in the rest of the world, are increasingly valued as Natural Climate Solutions (NCS) (Griscom et al. 2017). Yet alterations of natural disturbance regimes, such as increases in the frequency and severity of bark beetle outbreaks and wind events, may limit NCS solutions through reduced carbon storage capacity in European forests (Seidl et al. 2014). Thus, forest managers face major challenges as they seek adaptive forest management approaches. Research on all aspects of forest resilience – from flood control and hydrologic regulation, to forest road design, to silviculture for functional trait diversity – will be particularly relevant to the Carpathian region.

Also of concern is conservation of rare and under-represented forested communities and seral stages, including intact floodplain and riverine systems, as well as primary and old-growth forests (Sabatini et al. 2018). Research is needed to identify both protection priorities (Sabatini et al. 2020) as well as vulnerabilities in the face of climate change, invasive species, and illegal timber harvesting, the latter posing threats to forest ecosystems even more generally (Korn et al. 2013). Research investigating the role that natural



disturbances play in shaping landscape patterns, beta diversity in habitat and species distributions, and ecosystem service provisioning will be central to our agenda (Mikoláš et al. 2022).

To ensure sustainable and multifunctional development of forestry, good and participatory forest governance is key and focuses on local communities as key stakeholders for sustainability, including to achieve socio-economic and environmental performances. Participatory forest governance refers to processes and mechanisms that enable those people who have a direct stake in forest resources to be part of decision-making in all aspects of forest management, from managing resources to formulating and implementing institutional frameworks (FAO, 2012). In Carpathians conditions participatory forest governance would include institutional arrangements ranging from community ownership and management of forest resources to partnerships for forest management between the state and local communities, and devolution of management of forest resources from the state to individual households.



Small forest recovery cycle  
in natural spruce forest  
in Western Carpathians



Unmanaged forest  
after wind break,  
High Tatras,  
Slovakia

## Recommended topics

- Climate change effects, vulnerabilities, risks, and adaptation responses
- Invasive species effects on forest ecosystems
- Natural disturbance dynamics, including alteration of disturbance regimes and implications for habitat and ecosystem services
- Reforestation and restoration
- Ecological silviculture, including but not limited to close-to-nature forestry
- Forest biodiversity, including rare, threatened, and endangered species
- Forest carbon dynamics, carbon forestry, and implications for climate mitigation
- Protected areas and natural climate solutions
- Sustainable forest-based recreation
- Forest hydrology and relationships to flood regimes and risks
- Riparian ecology; forest-stream interactions; flood-plain forests
- Improving the region's forest road networks, design, and engineering
- Plant functional trait diversity and ecosystem resilience
- Primary, old-growth, and under-represented seral stages and communities
- Illegal timber harvesting and enforcement of country-specific forest laws



Close-to-nature-silviculture applied to a mixed species forest in the Czech Republic.

- Forest governance, including stakeholder involvement in decision making and community-based forest management
- Sustainable wood bioenergy and uncertainty regarding effects on carbon budgets
- Value-added wood products
- Non-timber forest products
- Good forest governance and forest stakeholders engagement in decision-making
- Innovations in forestry

## Recommended research questions

- What are the optimal criteria and methodologies for determining the most at risk forest resources, functions, and biological diversity in the region?
- What are the main challenges of sustaining forest ecosystems into an uncertain future?
- Which forest attributes and forest management approaches best confer resilience or adaptability to climate change?
- How can the forest sector contribute to climate change mitigation through forestry practices, restoration, and conservation promoting Natural Climate Solutions?

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## 7 Conservation and sustainable use of biodiversity



Pavel  
Cudlín

Healthy biodiversity is a background of diverse resources and services necessary for human survival, prosperity, and well-being (MEA, 2005). However, as a result of continued population and economic growth, it is declining globally at a historically rapid rate (Díaz et al., 2019). The Carpathian Mountains are a biodiversity hot-spot in European context, they harbour many relatively undisturbed ecosystems, e.g. large unmanaged old-growth (“virgin”) forests or Europe’s largest wolf and brown bear populations. In addition,



*Matteuccia struthiopteris*  
on western Beskydy wetland



Orchid *Orchis mascula*  
on western Beskydy  
meadows

Carpathians are still rich also in semi-natural, traditional landscapes (Bjørnsen-Gurung et al., 2009) supporting rich biodiversity.

Carpathians are very dynamic due to the transformation of a political and economic system at the end of the previous century followed by urbanisation and changes in land use. The loss of natural habitats is mostly caused by forest exploitation, land-use conversion, nutrient loading, pollution and by natural disturbances that are often a consequence of climate change (Primack, 2000). Recent spruce dieback in Carpathians could be considered as a threat to natural forests while in monocultures it could be considered as an opportunity.

The loss of near-natural habitats is mostly caused by termination of (traditional) management, their abandonment or shifts to intensive, production-oriented management practices. Effects of all these changes to biodiversity are still not sufficiently known and therefore the strategy of the management measures for biodiversity maintenance and protection of habitat and species diversity is needed.



*Salamandra salamandra*  
in western Beskydy forest



Upper timberline in the High Tatras, Slovakia

The recent EU policies, especially the European Biodiversity Strategy and Green Deal bring new inputs, e.g. in the field of ecosystem restoration.

## Recommended topics

- Revealing the most threatened habitats and species, preparation of action plans for the protection of these
- Finalisation of the draft Red List of Species and Red List of Forest Habitats (2014) with involvement of relevant experts from all Carpathian countries
- Identification of conflicts between humans and wildlife (build on experience from other mountainous regions in resolving wolf-livestock conflicts)<sup>2</sup> and of measures to their resolving or reconciling
- The effect of linear infrastructure development to fragmentation of wild animal populations and to animal-vehicle collisions; identify measures to prevent or reduce them

<sup>2</sup> <https://www.eurolargecarnivores.eu/en/feature/bruno-zaehner> (under AGRIDEA; in German).

- Impact of land use changes to natural and semi-natural habitats and their diversity
- Restoration of damaged or destroyed ecosystems
- As knowledge gaps exist of endemic and rare species for which the Carpathian countries have high responsibility, research on endemic taxa should be fostered
- Biodiversity-related data collection for spatial planning, landscape conservation
- Identification of ecosystem services provided by natural areas
- Addressing knowledge gaps in applying ecosystem approach, ecosystem services to humans, ecosystem effects to human health, methods of mapping and assessment of ecosystem services.

## Recommended research questions

- Which management measures for biodiversity maintenance and protection of habitat and species diversity can be applied and how, considering a long-term perspective?
- What are indirect effects of human activities to species/biodiversity?
- What are the effects of climate change on biodiversity?
- What are consequences of forestry management to biodiversity?
- How do invasive species impact natural ecosystems and their regulation?
- What are optimal sizes of large carnivores' populations in the Carpathians?
- How can knowledge gaps of human interaction with large carnivores be addressed?
- What are the effects of legal hunting on pack structure and behaviour?

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## 8 Ecosystem services and human well-being



Mariana  
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Maria  
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Piotr  
Mikołajczyk

Zbigniew  
Szkop

Ecosystem Services (ES) play an important role in economic and social development of mountain regions, e.g. being a source of wood and non wood forest products (NWFPs), a renewable energy source, and a basis for outdoor recreation, in addition to maintaining their ecological significance (e.g. for watershed protection, erosion control and biodiversity conservation). Mountain forests contribute to reducing societal vulnerability to climate change and to ensuring the well-being of local, forest-dependent communities. Attention is being increasingly paid to an improved understanding of human-environmental interactions within the Forest Socio-Ecological Systems (FSES) (Kalaba, 2014; Mohammed and Inoue, 2017). Recent studies seek to explain how forest ecosystems can contribute to human well-being and provide sustainably a broad array of essential ES (Melnykovich and Soloviy, 2014). Forest-dependent communities, such as mountain communities in the Carpathians, use ecosystems intensively because they depend on ES. Forest users and governance representatives at a local level influence the sustainability of FSES (Sarkki et al., 2017a). To date, however, mountain FSES, where communities are highly dependent on goods and services derived from forests and where human-environmental interactions remain a key factor for sustainable development, remain underexplored. Exploration of multi-functionality in forest social-ecological interactions constitutes a challenge, since the combination of ES may be different across different locations and contexts, and dependent on a high number of factors. Thus, it is imperative to examine the socio-ecological system complexity across a range of social and environmental interactions as well as the dynamics and cross scale issues that have multiple outcomes (Melnykovich et al., 2018;

Nijnik and Miller, 2013). Specifically, there is a lack of understanding of the flows of ES that contribute most to the well-being of communities that are highly dependent on forests, as it is in the Carpathian Mountains (Nijnik and Melnykovich, 2016; Melnykovich and Soloviy, 2014).

Knowledge of the economic value of ecosystem services can be extremely important for e.g. decision-makers. As part of the analysis of ecosystem services, the following main elements (stages) can be distinguished:

- assessment of ecosystems (type, condition, etc. – translating into the potential to provide services);
- assessment of services (which services and in what volume can be delivered by a given ecosystem in given state/condition);
- valuation of services (calculation of the value of services provided in monetary units).

Therefore, the proposed directions of expert, research activities by the S4C community, could possibly entail and/or focus on the following tasks related to the Carpathian:

- ecosystem mapping, taking into account the diversification of categories and characteristics of ecosystems with respect to their components and both biotic and abiotic elements and in relation to eco-landscapes zones, physiogeographical regions, and administrative division,
- select / develop credible indicators to understand (a) the state of ecosystems as well as (b) potential to deliver ecosystem services and (c) capacity to supply further the ecosystem services,
- communicate the value of ecosystem services to be included in policy making processes.

### Recommended topics

- Ecosystem services valuation for better decision making and good governance of nature
- Human-environmental interactions pertaining to ecosystem services demand and supply development of innovative responses to address contemporary challenges in ecosystem services supply and enhance systems' resilience
- Investigate the perception of ecosystem services by relevant stakeholders to integrate them in decision making
- Develop diverse development trajectories to overcome current challenges to sustainability of ecosystem services provision, with

- Identification of appropriate responses (e.g. social innovations and social-ecological innovations) to assist in overcoming the challenges and achieving sustainability in ecosystem services provision, including at a local scale

## Recommended research questions

- Which Ecosystem Services contribute most to the well-being of communities that are highly dependent on forests in the Carpathian Mountains?
- Which social and social-ecological innovations can assist in overcoming the challenges and achieving sustainability in ecosystem services provision to generate human well-being?

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## 9 Urban and rural development

Bogdan Andrei  
Mihai



Carpathian landscapes are well defined by thousands of settlements, permanent as well as temporary, developed along valleys and slopes and, very interestingly, on high mountain plateaus or remnants of the erosion surfaces, such as in the Romanian Carpathians – the Apuseni Mountains central regions with scattered villages located up to 1400–1500 m (Tara Motilor region). Urban development is another aspect, strongly related to the industrial tradition and to the transportation networks. Tourism development influenced the evolution and the reshaping of the built-up areas, especially after 1989, as the centralised urban planning was replaced by private initiatives and a secondary role of state decision makers. Inventory and mapping of these transformations in an unified way is highly important, with the objective to identify simultaneously the spatial and temporal patterns, as well as the main drivers and the potential directions of these processes. An inventory of settlements is necessary as we can observe a general trend of depopulation of rural areas, for example, in Romanian Carpathians, where poor infrastructure and limited investments poses challenges to maintaining rural landscapes with high cultural value and traditional experience (e.g. arable ground on top of hills and mountains disappears as explained by Savulescu et al., 2019). On the other hand, some urban areas, situated along mountain valleys with higher levels of transportation infrastructure (i.e. main railway lines, modernised highways, motorways) create high levels of urban pressure on the landscape, with increasing density of houses, including tourism-related developments, such as ski areas. These settlements are creating new urban landscapes in a shorter time interval (ex. after 2001 in Romania), where buildings are often constructed on slopes with old mass movements, previously covered by secondary forest stands from the 1950s (ex. Upper Prahova Valley in Southern Romanian Carpathians, see Mihai et al., 2014). Recent development of settlements shows a general trend of homogenization of functional features, as well as social changes, with the visible replacement of former

structures, typical for mountain communities, by population coming from big towns outside the mountain area, which contributed to the development of settlements by their real-estate investments. Social innovations might contribute significantly to urban and rural sustainable development objectives.

### Recommended topics

- Inventory and mapping of urban and rural development processes
- Identification of drivers for urban and rural development
- Depopulation of rural areas
- Socio-ecological trends in development of urban settlements

### Recommended research questions

- Is it still possible to define a Carpathian type of rural and urban settlements after the recent social and economic transformations?
- Can internal transformation of built-up areas in Carpathian settlements reflect the latest social and economic developments/evolutions? Is it possible to develop and standardise a methodology in this context, to be applied for the entire region?
- Which are the relationships between topographic background and the spatial and functional development of Carpathian rural and urban settlements?
- Is it possible to map in a standardised way the effects of the depopulation of the mountain areas?
- How can the relationship between Carpathian settlements and the accessibility of the mountain regions be evaluated and mapped, together with the development of transportation infrastructures?
- How can emerging transportation infrastructure affect the settlement's dynamics and their spatial, social and economic profile?



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## 10 Traditional Ecological Knowledge and Tourism



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Elena  
Matei

Traditional Ecological Knowledge (TEK) is increasingly understood as a key component of human engagement with ecosystems historically and moving forward. This is especially true in relatively isolated and challenging ecosystems that abound in mountainous regions such as the Carpathians (Moga 2016, Angelstam 2017). TEK is often a generative component of local traditions generally, and those traditions are featured as part of the creation of many tourist destinations. In the framework of sustainable tourism destinations development, where the setting up of equilibrium among environment quality, local communities benefits, tourist satisfaction and economic of investor welfare are required, TEK could be a driving force for all these sectors. Thus, more attention should be paid to research on tourist satisfaction with the originality of (eco)tourists products (Matei et al., 2014), functioning of environmental conservation areas (Widawskiet al., 2018) or sustainability of economic tourism business (Filimonau et al., 2020). However, the concept of “local communities” needs to be clarified and included as part of our research findings. In areas with strong tourism impact, we need to include the interactions between local communities who retain TEK, more recent migrants to any given area, and tourists (eg. for studies of traditional local residents, more recent settlers, and tourist trends in the Polish Tatra Mountain region as seen in Cooley 2005: 58–82; Dabrowski 2021). This research agenda will generate new knowledge about the ties and tensions between tourism as an economic driver and the pressure this puts on ecosystems and the local communities with long traditions of living symbiotically with delicate mountain environments. The topics proposed suggest the value of research teams that include specialists in the arts and humanities working collaboratively with environmental scientists, geographers, and others to develop new models for sustainable tourism. We ask if there are links between displacing local communities or replacing their land use practices,



Mountain lake in the High Tatras, Slovakia

and damaging local ecosystems. More positively, we ask if supporting or renewing traditional ecological knowledge and practices may help us restore damaged ecosystems, encourage resilience and enhance tourism values. As researchers, how can we better understand the impact of human cultural practices on ecosystems? Since environmental restoration efforts often rely on the active engagement of local stakeholders, understanding and respecting TEK may improve the success of S4C policy recommendations.

## Recommended topics

- Resilience, adaptations, innovations for sustainable Carpathian tourist destinations.
- Mapping of the entire region in a standardized way and the development of a living atlas of the Carpathian Region.

- Human-wildlife conflict in tourism-related research.
- Re-evaluating alternatives to existing understandings of ecotourism.
- Past, current, and future roles of Traditional Ecological Knowledge in maintaining resilient mountain ecosystems.
- The potential value of research teams that include specialists in the arts and humanities working collaboratively with environmental scientists, geographers, and others to develop new models for sustainable tourism.
- Scientists and humanists working together to propose new (and revive old) approaches to ecology in the Carpathians.
- Quantifying the tensions between slowing climate change to support regional ecosystems and tourism development to support economics.
- The incorporation into policy recommendations requires that Traditional Ecological Knowledge be respected and that traditional local stakeholders be part of any land use decisions.

## Recommended research questions

- How can we clarify the conception of “local communities” and their relationships to Traditional Ecological Knowledge?
- Is it desirable and possible to (a) openly recognize distinctions between populations who may be considered “traditional” to a region, and to (b) prioritize the traditional residents in particular regions as integral to our understanding of those regions’ ecologies?
- How might this impact tourism to these same regions?
- Where is it possible and helpful to defer to Traditional Ecological Knowledge (TEK) as interpreted by traditional residents of regions-of-interest as the starting point for any land use, including tourism?
- Make the causes of depopulation and population ageing a priority research question that precedes policy recommendations of tourism development.
- How to best change or pair the concept of “sustainability” with “resilience” since “to sustain” too often implies keeping things as they are rather than adapting to changing circumstances (see Allen 2019).
- Strengthen the link between the protection and valorisation of cultural heritage and climate mitigation.
- How might TEK be encouraged and in some cases adapted for present changing environmental conditions?

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## 11 Cultural heritage and traditional knowledge



Zsolt  
Molnár  
Marianna  
Biró

Katalin  
Mazsa  
Mariana  
Melnykovich

The richness and diversity of local cultures are part of the unique values of the Carpathian region, distinguishing it from other regions of Europe and the world. However, weakened knowledge of traditional land-use management and governance in local communities, decline of knowledge exchange and skill transfer between generations can be observed in the Carpathian region (Spacek, Melnykovich et al., 2022). The cultural heritage of the Carpathian region, in particular its intangible manifestations, is increasingly threatened, also by social transformations and changing economic conditions, the ongoing depopulation of rural areas particularly concerning marginalised mountain areas, and globalisation of culture, which can lead to its deterioration, abandonment and disappearance. Article 11 of the Carpathian Convention requires parties to pursue policies to preserve and protect cultural heritage and traditional knowledge, which includes cultural heritage, traditional knowledge, architecture, land use, animal husbandry, horticulture and botany (Carpathian Convention, 2003). Based on the Carpathian Convention documents pertaining to Cultural Heritage and Traditional Knowledge (e.g. the Draft Protocol on Cultural Heritage and Traditional Knowledge, etc.), discussed at the Fifth Meeting of the Working Group Cultural Heritage and Traditional Knowledge in 2018, in Szentendre, Hungary<sup>3</sup>, the following research topics and questions could be formulated as an aim for the near future.

<sup>3</sup> <http://www.carpathianconvention.org/eventdetailwg-cultural-heritage/events/fifth-meeting-of-the-wg-cultural-heritage-and-traditional-knowledge.html>



A high nature-value cultural landscape in the Eastern Carpathians

## Recommended topics

- Identification and mapping of the cultural heritage and traditional knowledge of the Carpathians;
- Inventory of the cultural heritage and traditional knowledge of the Carpathians;
- Traditional architecture in the Carpathians and its preservation;
- Preservation of cultural landscapes, traditional land-use patterns, local agricultural practices and breeds of domestic animals, cultivated plant varieties, sustainable traditional use of wild plants and land use practices.

- Raising awareness on cultural heritage and traditional ecological knowledge of the Carpathians.
- Promotion of cultural heritage and traditional knowledge through educational programs and research and social innovation projects;
- Promoting traditional value-added local products, arts and handicrafts ;

## Recommended research questions

- What are the specificities of the Carpathian region in relation to cultural heritage and traditional knowledge that could enrich the European and global level understanding of how to protect local and regional heritage? Best practices and region-specific options for research, protection and education.
- How soft tourism, the production of local 'labelled' products and the maintenance of local livestock breeds and crop varieties can help maintain local cultural heritage? What practices are harmful for the development and adaptation of local cultural heritage? What are the best possible ways to protect built cultural heritage? What is the role of built heritage in maintaining intangible heritage?
- What kind of species and ecosystem types are well known and used in the local ecological understanding in any given area by local traditional land users? What are the specific



Cultural heritage,  
Beskydy,  
Czech Republic

short- or long-term ecological processes that are recognized and are modified while using or managing natural resources? What ideas and understanding do traditional ecological knowledge (TEK) holders have of the causes of ecological change, including undesirable changes linked to their own practices, as well as drivers of change beyond their control, such as climate change or policies made by remote governments? How can TEK and modern resource management develop in parallel in an adaptive, dynamic way, what is the role of regulations and subsidies?

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# 12 Education for Sustainable Development



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The critical role of education for implementing the 2030 Agenda has been reiterated in academic and policy documents (i.e. Garcia et al 2017; UNESCO 2019). Moreover, how sustainable development is understood and achieved at local, national, and regional levels is subject to negotiation and societal learning (Barth 2016). Education for Sustainable Development (ESD), highlighted in SDG 4.7 (UN 2015), provides a framework for such societal learning. It advocates both for educational approaches, which facilitate societal transitions toward sustainable livelihoods, and for the use of sustainability as a learning context in order to enhance educational praxis (UNESCO 2014; Barth 2016). The recently

adopted United Nations Educational, Scientific and Cultural Organization (UNESCO) global framework on ESD for the period of 2020–2030 (ESD for 2030) builds on the results of the Global Action Programme (GAP) on ESD (UNESCO 2014). It provides guidance for further strengthening ESD as a tool for making progress in implementing SDGs (UNESCO 2019). Article 13 of the Carpathian Convention outlines provisions for awareness raising, education, and public participation (Borsa et al 2008). The Science for the Carpathians network, in collaboration with the Carpathian Convention Secretariat is facilitating stronger integration of ESD into the Convention Programme of Work, including by understanding challenges and possible pathways for enhancing implementation of ESD - related strategies in the Carpathian region and supporting the establishment of the Carpathian ESD Expert Network (Mitrofanenko, Varga and Zawiejska 2020).

## Recommended topics

- Integration of Real world labs and other transdisciplinary approaches into university education
- Life-long teacher education
- Integrating main research findings and applied knowledge into school and university curricula.
- Carpathian Identity in environmental education and education for sustainable development.
- Reconciliation of national differences and recognition of similarities in approaches to ESD.

## Recommended research questions

- What are previous experiences of networks related to or created in the framework of the Carpathian Convention? What can be learned from these experiences?
- What are the needs of the educational community - how the Carpathian ESD Expert network can contribute to the practitioners, to research at universities etc. (for example, development of specific guidelines for implementing ESD or other ESD-related concepts, with the view that we are operating in the framework of the Carpathian Convention)?
- How can we identify the needs, the quality of research, methods that should be further developed, barriers that can be overcome with the help of the ESD Network?



Activities in the field of Education on Sustainable Development carried out under the Carpathian Convention

- What are the connections within the ESD network at different levels - like universities and schools, research and practice.
  - How can we map these connections (network analysis?)
  - Can we enhance the connections? Do we want to do it? Who will do it?
- What potential strategies linked to learning, sharing and integration of knowledge can we use to address Carpathian Sustainability challenges? and which roles can specific actors plan in these strategies?

- **Role of the scientists / Universities / S4C**

- Could Universities support the process of collection of good examples?
- How can (academic) research institutes cooperate with the S4C in the activities on environmental education for teachers and pupils?
- How can the S4C and scientific community in general contribute to identifying and strengthening the links between Carpathian Convention activities, Informal, and Formal education?
- Could Universities (and other CC stakeholders) play a role in supporting teachers, and governments in integrating local / Carpathian issues into the curriculum?

- **Formal/ Informal /Non Formal Education**

- How can we integrate / strengthen learning / informal education components of Carpathian Convention activities?
- What are the good examples of ESD embodied in practical teaching-learning in the Carpathians?
- How do schools/teachers use the curricula and textbooks? How do they learn to be able to perform quality ESD? What obstacles do they overcome and how?

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# 13 Participatory research, multi-actor dialogues and knowledge co-production



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Addressing complex challenges of sustainable development requires integration of knowledge and competences, reaching beyond single disciplines and academic fields. Multi-stakeholder cooperation with science will bring benefit to the policies for sustainable development formulation and their implementation. This cooperation could bring a comprehensive and systematic approach to resolving the environmental and social challenges in the Carpathian region (Melnykovych et al., 2018). Participatory research and planning imply that various actors and stakeholders can help shape the research and foster multi-actor dialogue for sustainable development (Mitrofanenko et al. 2020). Participatory approaches (e.g. citizen science) can be applied in research, bringing together different academic and non-academic actors, including those who are affected by the issues addressed by the research and/or can contribute relevant knowledge to the research process, in order to co-produce knowledge and jointly elaborate actions to address the respective sustainability challenges (Enengel et al., 2012).

Recognizing and integrating different types of knowledge, and know-how, as well as interacting with different groups inside and outside academia can create more robust learning outcomes and contribute to awareness raising - a key process for sustainable development, which contributes to the rethinking and changing of mental models and behaviours, and helps to deal with new circumstances (Peer and Stoeglehner, 2013 in Mitrofanenko et al., 2020). Participatory research and planning are major components of transdisciplinary approaches, which aim at integrating knowledge across disciplines and sectors, enabling co-creation of knowledge and practices for addressing complex



A participatory workshop by the S4C with the Biodiversity Working Group of the Carpathian Convention

societal challenges and promoting what is perceived to be the common good (Pohl and Hadorn, 2007, Moulaert 2013).

## Recommended topics

- Local communities' participation in research e.g. through citizen science, living labs
- Participatory action research (Chevalier and Buckles 2019) and implementation Integrating inter-and transdisciplinary approaches and participatory methods connecting academia, local action groups and policy makers
- Promoting research on social innovation as a trigger for transformations towards sustainability in the Carpathians (through better collaborative links of science, local stakeholders, and policy makers to tackle the challenges that the mountainous region face).
- Promotion and dissemination of best practices and Social innovations initiatives - activities of local communities for tackling challenges that are not addressed by existing institutions or markets (e.g. activities for sustainable governance of landscapes along with promoting local culture, local food, tourism, creating value added local products, etc.).



## Recommended research questions

- What is the state of inter- and transdisciplinary research in the Carpathian region?
- What good examples exist of collaboration and co-creation of knowledge with local communities' in research in the Carpathian region?
- What are barriers to integrating participatory action research, inter- and transdisciplinary research as a common practice among scientists working in the Carpathian region?

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# 14 Social innovation to promote sustainable development



Social innovation (SI) is often seen as a force to promote sustainable development and steer a sustainable governance of nature. As a product of policy discourse, social innovation has led to the promotion of civic values as a means of delivering support to communities and enhancing sustainable use of ecosystem services where markets and existing institutions fail. Attention to social innovation has been rising. It is becoming particularly relevant in (marginalised) mountain regions, including of the Carpathian Mountains, where market imperfections and a shortage of public funding are obstacles on the way towards sustainability transformations.

It is important to analyse, design and ensure ways of how public and private sectors, various partnerships and collaborations can enhance, scale-up and scale-out social innovation in mountain areas and communities. Consideration and understanding of enablers and barriers to answer the question of how SI can deliver transformative opportunities to people (and socio-ecological systems) on the ground. For doing this, the initial steps suggested would be:

- 1) To define SI in the Carpathian context;
- 2) To create the Carpathian database of examples of SI and social-ecological innovations (under the Carpathian Convention Platform)
- 3) To popularize and share positive examples, advance the knowledge on SI and create a workable network between successful cases, providing and extending the opportunities for wider (transboundary) cooperation and SI diffusion.
- 4) To create tools for dissemination of scientific results for use by regional/local policy makers and other stakeholders (via policy briefs and practice guides).

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Nijnik

5) Seek for financial support (seed money) to enhance the emergence/growth of SI and help with its success.

## Recommended topics

- Productive mountains:
  - Food security
  - Security and human rights standards of value chains
  - Maintenance and stabilisation of regional production systems in European mountain areas, including agro-food systems as well as manufacturing.
- Comparative mountain research on different social practices and strategies with the approach of dichotomies:
  - Mountain distinction versus mountain/lowland linkages dichotomies.
  - Territorial cleavages vs. urban-rural linkages
  - Distinction vs. Inclusion
  - Isolation vs. Immigration
  - Production vs. Consumption
  - Environmental/cultural protection vs productivism.
  - Smart and resilient mountains

## Recommended research questions

- How to maintain balanced regional production systems in agriculture and manufacturing beyond the main tendency to leisure and residential functions in mountains?
- How to gain external new knowledge without losing one's own (traditional) competences?
- Has social innovation been shown to steer the development of disadvantaged communities towards sustainability? What are its examples? What are the opportunities, barriers, and trade-offs involved?
- What are the driving forces of social innovation and key observations as to its emergence and development? What are key determinants and scaling opportunities of social innovation?
- What are inter- and transdisciplinary approaches that foster social innovation? How can early involvement of expert and/or local/indigenous knowledge foster its development?

- What is the role of hierarchies (local, national, transnational) governance structures, private sectors, markets and networks, and various non-state actors, partnerships and collaborations in enabling social innovation and supporting different forms of its scaling up, out and deep?
- What are the principal causes of unevenness in social innovation? Do social capital and cultural differences play key roles? What's the role of nature and human-environmental interactions?
- Are actions of the state crucial in delivering more sustainable outcomes (social, institutional, environmental and economic)? To what extent does successful social innovation depend on drawing down public funds? What are other financial opportunities for social innovations to sustain and advance?
- What are policy implications of social innovation? To what extent and under what circumstances can social innovation deliver transformative opportunities to people on the ground? Can social innovation trigger the transition of governance/ policy system towards sustainability in the Carpathian Mountains?

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# 15 Green energy and energy efficiency



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Traditionally mountainous communities are deeply dependent on wood energy used to meet the heating demands of households and public buildings. However, despite increasing forest area and timber volume in this region during the last years, affordable bioenergy from forests remains scarce in many areas. At the same time, local communities suffer from energy scarcity, energy insecurity and high energy costs, and also experience lack of energy efficiency. In an effort to understand how to make better use of bioenergy resources, address sustainability goals as well as the needs of local communities, there is a need to assess the significance and future potential of wood energy and other renewable energy sources (wind, solar) for regional economies and households from an environmental, economic and social perspective. At the same time, application of innovative socio-ecological governance approaches, such as citizen energy communities (Ryszawska et al. 2021; Soloviy et al., 2019), should be explored, as a way to revitalise rural Carpathian areas.

## Recommended topics

- Social and technological innovations for transition to green renewable energy (RE)
- Energy efficiency
- Reasons for the scarcity of affordable bioenergy sources
- Knowledge and technology transfer to local communities to support their energy efficiency along with climate mitigation efforts (afforestation programs)
- Community-driven bioenergy initiatives (e.g. local cooperatives)
- Best practices of energy strategies embedded in the local economic development strategy so that they reflect local potential and needs

- Integration of REs within larger supply chains in rural economies, such as agriculture, forestry, traditional manufacturing and green tourism
- Use of REs resources appropriate for the specific areas and focus on relatively mature technologies such as heat from biomass
- Establishment of integrated energy systems based on small grids able to support manufacturing activities
- Social acceptance of green energy projects by engaging local communities in the process

## Recommended research questions

- What is the potential for sustainable green energy in the Carpathians?
- What innovative renewable energy initiatives are currently implemented in the regions and how do they contribute to sustainability and building resilience to future energy challenges?
- What kinds of (social and technological) innovations in the field of renewable energy and energy efficiency could promote local development in the region?
- What is the power of co-creation of energy transition with multiple stakeholders?
- What are the supportive policies for energy transition in the Carpathians ?

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## 16 Data Management



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Availability of high-quality Data, its proper management and use are prerequisites for scientific inquiry, understanding socio-ecological processes and addressing socio-ecological challenges. Historical data in digital form is increasingly available in the Carpathian region. Long-term processes and phenomena will be easily detectable in many research areas in the Carpathians thanks to increasing availability of historical data. A way forward in this respect could involve building a unified geodatabase with all the available historical aerial and remote sensing imagery at higher resolutions for the entire Carpathian region – for example, DECLASS 1 and 2 imagery from USGS are available for the former Eastern European countries and can be processed as historical orthoimages to be integrated in landscape change mapping and analysis (Mihai et al., 2016, Nistor et al., 2017, Niță et al., 2018, Jabs-Sobocinska et al., 2021). LiDAR landscape palimpsest could be used for mapping and identifying current and historical anthropogenic landscape features. However, LiDAR can also be used for mapping soil degradation and geomorphic processes. As LiDAR data are becoming available in Carpathian countries, collecting available LiDAR data for a unified LiDAR dataset for Carpathians is recommended. Systematic integration of the available ESA Copernicus complementary satellite data could help generate maps, based on derived models, covering the Carpathian mountains and the neighbouring regions.

### Recommended topics

- Applications of historical data in geography, land use, ecology and conservation
- Advances in Earth observations for sustainable development in mountainous regions:
  - Systematic integration of the available ESA Copernicus complementary satellite data (free access, starts from 2014) in regional scale analysis for Carpathian environmental mapping in a unified formula for the entire region.

- Development of unified semi-automatic/automatic approaches for land cover change mapping in the Carpathian Region, by integrating panchromatic aerial and satellite analogical imagery with recent multispectral digital imagery, in order to generate synthetic maps for the entire region.

## Recommended research questions

- How is it possible to validate by fieldwork the mountain landscape changes in last decades reforested areas, after the remote sensing integrated approach?
- Could we reconstruct traditional farming landscapes in mountain areas by integrating historical data with remote sensing data, including LiDAR?
- Which are the most objective radiometric indices derived from Sentinels data to be adapted for the mapping of the entire Carpathian Region? Is it possible to propose a broad validation of them with field data and other independent data (ex. wildfire events inventorying data – see Mihai et al., 2019).

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## Science for the Carpathians (S4C)

We are the network that connects scientists around the globe working on the Carpathians, defines research priorities for the region and enhances international collaboration with partners from outside the Carpathians.

Science for the Carpathians was established in 2008.

Our objectives:

- Develop and implement the „Research Agenda for the Carpathians“
- Promote research coordination and collaborations across disciplines and national boundaries
- Advocate for a Carpathian research area towards pan-Carpathian research
- Facilitate the development of peer-reviewed papers and synthesis articles
- Foster dialogue between research, policy and practice

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