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Science for the Carpathians



HUMAN-ENVIRONMENTAL SYSTEM
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WATER RESOURCES AND MANAGEMENT

Riparian Zone Monitoring and Change Detection using Machine Learning Techniques

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Understanding the dynamics of vegetation in river systems is of paramount importance due to its significant influence on sedimentation patterns and biodiversity within riparian zones. The main contribution of this study aims to advance the field of change detection in riparian zones through the utilization of spatio-temporal classification methodologies. Specifically, the research focuses on monitoring the evolution of vegetation dynamics on the revitalized Danube River's side arms. Employing advanced machine learning algorithms for automated satellite data classification effectively distinguishes vegetation responses to natural succession and human-induced impacts within the riparian zone. The proposed method involves a comprehensive analysis of temporal and spatial changes in vegetation, exploring the relationships between environmental parameters and vegetation dynamics, evaluating the effects of diverse environmental factors and human activities on vegetation spectral responses, and monitoring the health of vegetation before and after revitalization in riparian zones. Through these contributions, this innovative research significantly enhances our understanding of riparian vegetation dynamics and aids in the development and implementing effective river management strategies for sustainable ecosystems.

Keywords: *Change Detection, Vegetation Dynamic, Classification, Machine Learning, Riparian Zone*

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Prediction of sediment transport after river training of the multi-thread river system in Slovak Carpathians

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Sediment plays a crucial role in shaping river morphology, especially during the construction of hydraulic structures or when managing flood activities. Understanding sediment transport characteristics within a river reach is essential for design engineers to address associated challenges. In the case of the gravel-bed braided-wandering Belá River, management strategies have been implemented to modify sediment patterns, resulting in significant aggradation and erosion. Therefore, investigating sediment transport and riverbed characteristics is critical to mitigate issues arising from changes in river morphology. The study focuses on river reaches selected based on river training sections. To analyze sediment transport, the Hydrologic Engineering Center's River Analysis System (HEC-RAS) was employed to develop a hydraulic model. Geometric data was derived from a Digital Elevation Model with a resolution of 5 meters x 5 meters using HEC-RAS. Calibration and validation of the model were performed using various sediment transport functions and Manning's roughness coefficient. The model's output provides insights into bed change patterns and identifies areas of erosion or deposition, allowing for a detailed understanding of the bed change patterns along the river reach and pinpointing specific areas experiencing erosion or deposition processes. By combining the model output with local knowledge, effective mitigation strategies can be implemented to address sediment-related challenges in river management following river training activities.

Keywords: HEC-RAS, DEM, Sediment Transport, River Training, Manning Coefficient.

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Floodplain levels identification and delimitation along the degraded river system in submontane area based on the multi-sourced data.

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The river floodplains, stretching along the watercourses, represent a unique and unmistakable feature of the landscape. They are formed and reworked mostly by migration and accretion of the rivers, creates mosaics of multi-aged floodplain units. Lateral shifting and channel migration are dynamic in a time and space, resulting in uneven inputs, accumulation, and erosion of material from the river channel and river floodplain. An asymmetrical character of the river floodplain is predominantly noticeable along braided rivers in submontane area. Vertical level of floodplain and its differentiation can be strongly affected by climate and anthropogenic changes, and by land use modification. a river incision led by human activity can result to the floodplain level formation and disturb connection between the channel and the river floodplain. Age determination of the river floodplain is possible based on the former position of the river, using aerial photographs. Nevertheless, we find a limitation in spatial representation of elevation difference, between the river channel and the floodplain. Based on the Relative Elevation Model (REM), we can identify different stages of river floodplain development and estimate the age of formation. The methodology is applied on the submontane Belá River, in the Slovak Carpathians. The river is characterized by a multi-thread channel planform, distinctive by degradation. The main contribution of the study includes not only to evaluate a planar modification of the Belá River floodplain, but also vertical changes presented in planar variation.

Keywords: *floodplain development, incision, relative elevation model, The Belá River*

Acknowledgment: *This research was supported by the Science Grant Agency (VEGA) of the Ministry of Education of the Slovak Republic and the Slovak Academy of Sciences (02/0086/21).*

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Exploring poorly understood blackwater streams of the Tatra Mountain foreland, Polish Carpathians

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Streams and rivers with high levels of tannins from decaying organic matter can display colours ranging from amber to deep brown and have unique chemistry; including notably low pH levels. These unique systems, often referred to as blackwater, occur in specific environments of the Polish landscape and elsewhere in the world. Compared to non-blackwater systems, blackwaters represent a poorly understood aquatic resource. Consequently, those charged with the management of blackwater systems have no choice but to rely on information gleaned from the study of non-blackwaters systems. This includes a poor understanding of how natural factors and anthropogenic activities impact existing conditions in blackwater streams. This general lack of scientific understanding of blackwater systems can easily result in highly erroneous stream management decisions.

We explored several blackwater streams located in the Orawa-Nowy Targ Basin of Southern Poland. This area is characterized by unfavourable climatic conditions and relatively poor soils which has limited agricultural use and development in the basin. Present human activities include logging, small scale farming, and more importantly, inputs into the stream system from local sewage and farming operations. Past attempts to drain the peat wetlands and enhance agriculture are still clearly visible in the landscape of today, including alterations of stream channel form. However, the area remains largely undeveloped and overall anthropogenic impacts are limited.

The specific systems we studied were located in the forelands of the Tatra Mountains and drain extensive fen areas. Over the last decade, many of the streams in this relatively secluded area have been colonized by beaver (*Castor fiber*) resulting in profound hydrological and geomorphic change and rapid restoration of some of the altered streams. The unique combination of physical conditions that limited human interest in the area has consequently allowed relatively natural functioning of the stream systems and provides a good opportunity to characterize blackwater streams and shed light on their ecological value and status. Many of these systems could possibly warrant

protection or, at a minimum, provide scientific data for adequate and informed management of these streams. This paper focuses on the results of the preliminary research conducted on the aforementioned blackwater streams of the Tatra Mountains foreland.

Keywords: *blackwater rivers, Tatra Mountains foreland, beaver impacts, river ecology*

Recent hydro-geomorphic response to extreme rainfalls in high-mountain catchment of the Javorinka creek (The Tatra Mts., Slovakia)

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Numerous studies document the importance of precipitation in the high mountain region of the Western Carpathians in the last two decades. The trend of increasing values of precipitation totals confirms the increasing effect of fluviation and water induced geomorphic processes. Correlations of the events like flash floods, debris flows or shallow landslides with heavy rain values measured within a single catchment area are not always unambiguous. Especially supercell rainstorms, due to limited spatial dimensions, are often not recorded by meteorostations sparsely distributed in the territory. The solution can be the use of data derived from ground Doppler weather radar imagery. The objective of our research is to provide spatiotemporal information on the effects of extreme rainfalls inducing the hydro-geomorphic processes with considerable impact on landscape and human activities in the Javorinka creek catchment area. Methods are based on the analysis of multi-temporal data from the last decade (very high-resolution aerial imagery, including UAV mapping products), geomorphometric parametrization of the aerial LiDAR-based DEM, and hydroclimatic data from meteorostations and ground weather radar. During the last decade, the most effective hydro-geomorphic process with catastrophic response within the catchment area was the single flash flood event in July 2018, when the precipitation values exceeded 150 mm per day (Kolové pleso meteorostation). The stream beds have been reshaped and enlarged their area twice (Javorinka +121% in mapped 4 km transect; Medodolský potok +102% in 1.5 km). The increasing frequency of daily precipitation totals above 40 mm during the last decades is reflected in the occurrence of vegetation-soil mantle disturbances (shallow landslides and debris flows). From the period of 2015-2022, we have identified and classified more than 100 examples of such events within the catchment area.

Keywords: *hydro-geomorphic processes, flash floods, riverbed evolution, debris flows, shallow landslides*

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Functioning of a mountain river in the Anthropocene – the example of Ochotnica River (Gorce, Western Carpathians)

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In addition to climate change, the impact of human activity plays an important role in landscape transformation. Fluvial systems are also subject to change, which can take place at different rates depending on the geographical location. In the case of mountainous areas, the effects of human activity on fluvial systems mainly concern changes in the land cover of the catchment and the hydro-technical development of the valley floor, which alters the circulation of energy and matter in the catchment. The effect of indirect and direct human activity changes the functioning of the fluvial system. Their reflection is the transformation of the morphodynamic structure of the channels and changes in the type and dynamics of processes that shape river channels. The Ochotnica riverbed was covered by a detailed study. Field surveys and analyses were conducted to determine changes in the functioning of this mountain river. In 2021, a geomorphological mapping of the riverbed was carried out, the results of which were compared with the results of studies carried out in 1984 and 2001. It was shown that the morphodynamic structure of the Ochotnica riverbed has become more complex. In addition, analyses of land cover changes in the Ochotnica River catchment in the period 1930-2019 were carried out. Moreover, a detailed analysis of the riverbed shape and active zone in the section that in the past took the character of a rift river was also carried out. These analyses were carried out based on archival cartographic materials (such as the Second Military Survey of the Habsburg Empire, aerial photographs, and orthophotos). The results indicate that erosional processes currently prevail in the Ochotnica River channel, which translates into a reduction in the number of accumulation forms and further deepening of the channel. These changes result in the concentration of flows in the narrow channel, causing a faster outflow of water.

Keywords: mountain river, structure of river bed, land cover change, human impact

CULTURAL HERITAGE AND TRADITIONAL KNOWLEDGE

Traditional Ecological Knowledge, Performance Traditions, and Education in the Polish Tatras

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The Highlanders (górale) of the Polish Tatra Mountain region are famous for their characteristic, still lively/living cultural practices including performance traditions (music, dance, dialect, poetry) and material traditions (costumes, architecture, musical instruments, and so forth). These iconic traditions are directly related to living in the often-hostile Tatra landscape, including transhumant shepherding historically found throughout the Carpathians. As recent studies reaffirm, transhumant pastoralism and other traditional land-use policies informed by Traditional Ecological Knowledge (TEK) encourage biodiversity, reduce greenhouse emissions, and tend to be both sustainable and resilient.^{1,2,3} While performative and material traditions retain considerable support from local communities and the tourism industry, labor-intensive traditional land-use practices are not adequately rewarded by current economic and land-use policies and priorities.

In this presentation, we ask if innovative and integrated approaches to traditions in the Tatras may encourage resilient ecological renewal.⁴ We focus on the historic and material connections between pastoralism in the region and the music, dance, dialect, costumes, and architecture. This includes music genres specifically about the mountains and pastoralism, dialect terms for mountain flora and fauna, and the role of locally produced materials for costumes that still play a central role in the performance of local highlander identity. Our recent ethnographic research suggests that intergenerational transmission of TEK is increasingly separated from performance traditions and material traditions. However, innovative educational materials⁵ plus local and EU policy initiatives may present ways to reintegrate core agricultural, performative, and material traditions that renew resilient ecological land-use practices.⁶

Keywords: *Traditional Ecological Knowledge, Education, Pastoralism, Performance Traditions, Material Traditions, Tourism, Heritage.*

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Transhumance today – knowledge, rules, heritage, production, communication – many professions in one

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The Europe-wide TRANSFARM project is an innovative educational project for practitioners co-financed by the Erasmus+ Program within the action: Vocational Education and Training, Cooperation Partnerships in Vocational Education and Training. The acronym TRANSFARM binds transhumance and farming. Transhumance is an agricultural system that involves seasonal movement of livestock from winter stables to summer pastures. It is a rare form of agricultural land use with specific requirements for land, livestock and personnel. The system is considered as a sustainable way of land management, and also as a response to pressure of social challenges. Transhumance has a cross-sectoral effect. The economic efficiency of animal production is important for agriculture. Alongside the seasonal grazing contributes to the provision of adequate management of protected habitats and the preservation of landscape. It is also linked to a specific culture. Unique musical instruments, typical dairy products and folklore traditions attract domestic and foreign tourists. Services in the field of tourism and recreation help to diversify structure of rural employment, which is still mostly linked to agricultural production. Despite the positive effects and societal benefits of transhumance, practitioners are at risk of being excluded from lifelong learning due to nature of their job, usually located in remote mountain areas. Therefore, online training education can be beneficial and helpful for this specific group of practitioners. One of the study areas is the Slovenský kras National Park, Biosphere Reserve and Natura 2000 sharing border with Hungary. Its cave systems were inscribed on the UNESCO World Heritage List together with adjacent caves in the Aggtelek Karst in Hungary in 1995. Currently, analysis of totally 18 case studies from different European countries is in the process. Finally a freely available education and training material for practitioners will be published in 8 languages.

Keywords: rural development, environment-friendly pastoralism, education, Biosphere Reserve, biocultural values

Disappearing witnesses to traditional management of hay meadows in northern Slovakia

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In the past the hay meadows of northern Slovakia were characterised by two main elements: solitaires of trees and shrubs and haylofts.

The trees and shrubs in the meadows were left to produce "letnina" (cut branches of deciduous trees for winter feeding of domestic animals that were tied into bundles and dried), which was the main winter fodder for sheep in the mountainous regions of Slovakia until the end of the 19th century (Podolák, 1982). The trees were used for the construction of haylofts, or sheepfolds. The lower branches of trees were cut off, such trees shaded the meadows less and there was less fallout. The branches were used as firewood in huts by shepherds.

Haylofts were log buildings with shingle roofs that were used to store the hay over the winter. The hay was put into them through an opening in the roof on either one or both sides. Altogether, we have identified 9,742 haylofts in Slovakia according to Czechoslovakian military topographic maps from 1952–1957 at a scale of 1:25 000. The data was processed using ArcMap 10.3 software.

Typical hay meadows with a significant representation of woody vegetation, and together with the haylofts created the traditional landscape scenery of the region. Until today, almost none of the former hay meadows with haylofts and solitary trees have been preserved. Some witnesses of former meadow management have survived due to the enthusiasm of their owners, but most of them have already disappeared or continue to decay.

Keywords: *Hayloft, solitaires of trees,*

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Lidar as a tool for mapping of historical anthropogenic features in traditional viticultural landscape of Svätý Jur (Slovakia)

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In recent years, the use of airborne laser scanning (LiDAR) has become increasingly common in cultural landscape studies. It provides detailed information about the terrain morphology and therefore become an important tool in mapping both natural and anthropogenic geomorphic features. It helps us to reveal structures in the landscape that are difficult to capture in field mapping. Following groups of anthropogenic landforms could be mapped with the LiDAR data: symbolic, habitation, transport, subsistence, mining, water, refuse or warfare^{1,2}. Svätý Jur represents an important historical site. The area was permanently inhabited as early as the Hallstatt period (750 – 450 BC). The area became an important centre controlled by a Hillfort-Neštich above the town in the early medieval period. Later, after the fall of Great Moravia, the nobility relocated to the Biely Kameň Castle. At that time, we already have a documented wine-growing tradition in the area. The inhabitants of Svätý Jur focused on viticulture and Jur became one of the wine-growing towns in the oldest wine-growing region in Slovakia. Thanks to Lidar, we have been able to map the remains of the medieval settlement, the medieval road system, abandoned vineyards with stonewalls, military structures and more. By mapping past human activities in the area we would like to show the richness and diversity of the anthropogenic features in cultural landscape of Svätý Jur locality.

Keywords: *Svätý Jur, LiDAR, historical anthropogenic features, cultural landscape*

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Early medieval hillforts in vicinity of polish Carpathians – localisation factors and multidimensional relations with the use of GIS tools

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The presentation concerns an interdisciplinary preliminary attempt to characterize the relationship between early medieval hillforts in Polish Carpathians. It concerns social, natural and geoinformatic analysis which will be presented, based on the locations of hillforts, data related to results of available archaeological research as well as literature and cartographic or historical sources.

A hierarchical classification of hillforts was created due to their purpose and functions - based on a database made in ArcGIS Pro. On its basis, it is possible to try to retrospect the former socio-economic system of the areas from Cieszyn to Przemyśl, within the influence of the emerging tribal dominions and later monarchies - mainly Polish and Ruthenian. The time range of the study concerns the 8th-13th century.

Methods for determining the hierarchy of hillforts and making polygons based on their locations include: vectorizing of hillforts, transferring relevant informations to attribute table, determining the hierarchy using hillfort classification, generating polygons and schematic multidimensional visualisations

These hillforts were combined into a network of dependencies and polygons based on W. Christaller's theory. They were compared with the range of the castellany (f.ex. Biecz, Wojnicz) of the historical area of Lesser Poland and Rus (Żaki 1974). Relations between hillforts, taking into account the hinterland, played an important role in shaping the defense systems and the countries in which they were located.

The result is a map of polygons built on a point vector layer of hillforts in today's Polish part of the Carpathians. In comparison with the publication (Konstantinovski Pontos, Luc 2022) it shows an example of space-time analysis. It has been shown that both Przemyśl (mostly until the 11th century) and Sanok (from the 12th century) in particular performed the highest significant defensive and social functions in the eastern part of the region.

Keywords: Hillforts, Medieval, Carpathians, Geoarchaeology, Geoinformatics

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NATURAL HAZARDS AND RISKS

Root plates of uprooted trees – detection and volume estimation using LiDAR point clouds

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Tree uprooting is one of the most important biotic-abiotic interactions in temperate forests. Geomorphic effects of this process should not be omitted. These effects include the formation of the so-called root plates, i.e. the micro-relief forms consisting of undecomposed tree root systems and the soil and rock particles attached to the roots. Root plates can be considered in terms of biotransport, i.e. the movement of soil and rock material caused by living organisms (Schaetzl et al., 1990; Šamonil et al., 2015).

The objective of the project was to develop an automatic unsupervised method of root plate detection and biotransport estimation, based on LiDAR point cloud data. Analysis was carried out for study areas located in the Polish Western Carpathians (Babia Góra National Park, Gorce National Park). The data sources were: 1) open source point clouds from the Polish Head Office of Geodesy and Cartography and 2) point clouds obtained from the administration of the national parks. To detect root plates, we produced the differential model (DM) indicating the location of uprooted trees. For this task, we applied two approaches: 1) taking into consideration ground points and points located less than 3 m above the ground, and 2) double classification of ground points with the use of cloth simulation function (CSF; Zhang et al. 2016). We applied closed contour lines to delineate the boundaries of root plates. Then, we estimated the volume of root plates by summing: 1) the values of DM within the root plate boundaries, and 2) the surfaces of each contour line within the root plate boundaries. To validate our results, we measured the location (GNSS receiver) and dimensions of root plates in the field. We applied this data to calculate the volume of root plates. The accuracy of root plate detection is at the level of 60%. The methods may be used in forest management and in the research on the impact of hurricane-force winds on forest ecosystems.

Keywords: tree uprooting, biotransport, root plates, LiDAR point cloud, Polish Carpathians

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Analysis of historical changes in planform geometry of a mountain river to inform design of erodible river corridor

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The Biała is a gravel-bed river in the Polish Carpathians that was severely affected by human activity over the last century. The analysis of changes in planform geometry of the Biała during the last 130 years were used to diagnose hydromorphological river degradation and thus to verify the need of river restoration. The study used topographic maps from 1878, 1935 and 1962, aerial photos from 1967, 1977 and 1987, and orthophotos from 1998 and 2009. For each date, boundaries of active river zone and river geomorphic units were digitized and their average width in 8 river reaches was determined. Overlays of an extent of active river zone from all analysed dates indicated the belt of river migration during the last 130 years. a comparison of contemporary river width with the largest river width recorded during the study period indicated the degree of river narrowing caused by its channelization and channel incision.

As a result of river channelization followed by channel incision, during the study period the width of the Biała was reduced to 16%–57% of its width in 1878. The river narrowing was associated with a reduction in the proportion of channel bars in the total river width and nearly complete elimination of islands. All these changes demonstrated the degradation of hydromorphological integrity of the river and the need for its restoration by allowing free channel development in an erodible corridor. The belt of the river migration during the last 130 years was ~5 times wider than the contemporary river. This justified delimiting the erodible river corridor on a substantially larger area of the valley floor than the area of the river in 2009. In 2009 the river was narrower than the largest river width recorded between 1878 and 1998 along nearly the whole length of the study river sections. These changes negatively affected the ecological river state (Wyżga et al., 2013) and increased flood hazard in the river valley (Hajdukiewicz et al., 2016).

Keywords: channel changes; river narrowing; hydromorphological river degradation; erodible river corridor; river migration belt

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Architecture of a regional geodatabase for hazard and vulnerability assessment in coal mining areas in SW Romania

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Mining and post-mining activities, due to their many impacts (vibrations, mechanical/chemical weathering, unstable sterile piles, denudation on exposed bed/sloppy waste rocks) are direct or indirect responsible for triggering geomorphic (landslides, earthflows), hydro-morphological (river dynamics and flash floods) and hydrological (river dynamics, changes in rivers' sediment delivery rates) processes.

Although current EU legislation on mining and conservation of sites after mine closure sets cautious limits for actions or inactions that could affect the environment, their effects are expected to worsen due to climate change. Among others, coal mining and processing activities can cause potential damage to the environment, given their wide spatial impact, affecting slopes and riverbeds, especially in the upper sectors.

Our study aims to evaluate the risk potential of the coal industry in the Southwest Oltenia Development Region of Romania, via a GIS database and integrated analyses. In this region, stretching over the Getic Subcarpathian and Piedmont units of the Southern Carpathians, two mining areas are located: Motru Rovinari (West), and Alunu-Berbesti (East), where lignite and brown coal are mined in open pits and, to a lesser extent, in underground mines.

In our geospatial database, various mining objectives in the two basins were mapped (open pits, tailings dumps, settling ponds), together with the permanent and temporary hydrographic network (to analyze its exposure to slope processes and hydrological phenomena). To investigate the risk potential, the actual (hydro)-geomorphological processes (landslides, earthflows, riverbed dynamics) were inventoried from aerial images. The regional database was completed by socio-economic and demographic variables (total population, demographic and socio-economic structures, infrastructure), which were further valorised through indexes assessing the vulnerability to slope-river process in settlements with coal-mining area/industry.

The evaluations on the coverage and connectivity of the mining objectives and the potential geomorphological and hydrological processes on the

hydrographic network were capitalized through spatial analyses, highlighting the current degree of exposure of the coal mining basins in terms of existing processes and future trajectories of evolution.

Keywords: *coal mining, geodatabase, geomorphic processes, hydrological hazards, Southwest Romania*

Developing of landslide relief during the Holocene. Geomorphological reconstructions based on paleoenvironmental biogenic data from Mt. Śnieżnica landslide (Beskid Wyspowy Mts.)

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The Outer Western Carpathians is a region very susceptible to landslides. They are both geo-hazards nowadays and the bank of paleoenvironmental data from thousands of years. The researched landslide is located on the north-eastern side of Mt. Śnieżnica, massif in the Beskid Wyspowy Mountains (1,006 m a.s.l.). Organic matter, including tree trunks in the stream bed and fen deposits, was discovered in the area. Geomorphological mapping and radiocarbon dating were employed to reconstruct the development of the landslide relief (Pawlik et al. 2022).

The origin of the landslide was dated to 13,466-13,749 (95%) cal BP, based on the oldest tree trunk found between bedrock and colluvium. Fan deposits began accumulating between 4,147-4,626 (75.2%) cal BP, indicating the reactivation of the main scarp and the formation of ramparts, resulting in a drainless depression. a second tree trunk, also found between bedrock and colluvium (580-650 (78.8%) cal BP), provides evidence of significant reshaping of the upper part of the landslide relief. a tree root dating to 312-471 (94.4%) cal BP, discovered in the stream bottom, indicates a young stream network in this area, which began forming four hundred years ago.

The dated phases of landslide relief development correspond with humid periods proposed by Margielewski et al. (2018). However, they also raise several questions. The research area is one of the oldest documented landslides in the Polish Carpathians. The most significant question mark

pertains to a gap of approximately nine thousand years, which does not leave any record in organic deposits. Is this gap a local anomaly, or were the very humid periods recorded in other landslides in the region not as morphogenetically significant? An important conclusion relates to the stream network. Our research demonstrates that a stream network on a landslide body can form much faster than is typically considered, and four hundred years may be sufficient time for its development.

Keywords: *landslide, relief development, paleoenvironmental reconstruction, Śnieżnica Mt., Outer Western Carpathians*

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The geomorphological hazards associated with climatic change in high-mountain Carpathian region - High Tatra Mts. (Slovakia)

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Accelerating global climate change affects all natural and socioeconomic spheres, but high-mountain areas are most attacked. The consequence of the exposed, dynamic relief of the High Tatra Mts. (the result of deglaciation) is the activity of geomorphological processes, conditioned and intensified by the current climate regime and extremes. The montane and, above all, alpine areas of the Carpathians will thus face major geomorphological events that will fundamentally change and influence individual ecosystems and their development but also represent natural dangers and risks for humans. This is also indicated by the events from the beginning of the summer of 2022, when in mid-June, during a sudden significant warming and defrosting of the rocks, a large rock avalanche was released from the northern summit wall of peak Malý Kežmarský štít. The debris cone from this wall enters two lakes - primarily to the Zelené (Kežmarské) pleso and then also the Čierne (Kežmarské) pleso - and undoubtedly affects the current state, changes, and existence of these lake ecosystems. The runway of the rock avalanche passed through a popular and highly visited climbing route - the Nemecký rebrík and ended at the hiking trail of the Tatranská magistrála. The aim of the contribution is the presentation of a case study on the area of valley Zelená (Kežmarská) dolina, which is part of the investigated areas of an on-going project focused on landscape changes and the spatiotemporal expansion of geomorphological processes in the catchments of the High Tatra lakes, pointing out the impacts of a changing climate. And reflecting on how these changes will affect these important natural water sources, supplying the valley systems and human activities in this environment.

Note: "Pleso" means the glacial lake or tarn [in Slovak]. "Staw" has the same meaning [in Polish].

Keywords: (Sub)Alpine Lake, Climate Extremes, Catchment Changes, Water State Changes, Climbing Routes Crumble

Acknowledgment: This contribution was created as part of the projects: VEGA 1/0546/21 Landscape change in the catchments of the High Tatra lakes; UGA VIII/4/2023 Analysis of the dynamics and spatial differentiation of morphodynamic processes in the catchments of the High Tatra lakes and their future development; UGA VIII/7/2023 Assessment of selected environmental impacts on the current physico - chemical state of lakes in the High Tatra Mts.

Accurate Mapping of Soil Erosion in Complementary Romanian Subcarpathian Areas. Integration of multisensor and multirate satellite images with systematic field pedological survey validation.

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Subcarpathian regions of Romania are featured by a highly fragmented land cover and by an intensive landscape transformation during the last 150 years, when traditional economy based on fruit growing and grazing is gradually replaced by oil, gas, coal and salt mining and an intensive urbanization as well. The imprint of these transformations visibly occurs through the effects of soil erosion and mass movements (Poesen, 2018) in Prahova Subcarpathian region (400-1000 m asl.), where our study tries to propose an integrated approach based on remote sensing – mapping and soil cover survey, as a basic step in developing a decision-making instrument for local/regional territorial planning.

Two study area are considered for our analysis. They were selected on the basis of soil erosion susceptibility map (Panagos et al., 2014). First is a sub-montane hills and plateau region between Slănic and Bughea rivers with overgrazing activity and orchard surface rapid decrease. Second is a typical oil mining landscape area of the Țintea Hills, with more than one century oil well development and a dense fragmentation of forest stands and pastureland.

Our objectives are the mapping of soil eroded occurrences on the basis of their spectral signatures' differences and the mapping of the soil erosion intensity on these patches by integrating data derived from satellite image processing. Third it was the validation of the output with field data from soil surveying.

Methodology has three levels. First it is a thematic classification of eroded terrain based on a data stack integration of Sentinel-1 SAR and Sentinel-2 MSI multirate images from all the seasons of the year, using comparative Machine Learning (ML) approaches (Alexakis et al., 2019) after a selective and intensive training in the context of a complex mosaicked land cover and land use pattern. Second is a data mining approach in searching the most suitable combination of spectral and biophysical decorrelated indices (Puentes et al., 2019), integrated for soil erosion intensity mapping, from the highest level of

erosion (rock layers occurrences) to the lowest level (superficial soil horizon occurrence).

Validation of the produced layers is done with the help of selected soil profiles on representative sites, to extract the accuracy parameters and prepare an improved formula of the erosion land thematic layers. These are compared with standard soil profiles from FAO and Romanian soil taxonomic systems in order to assign the intensity of erosion.

The ML classification of the three classes of eroded land returned and overall accuracy of 70% coefficient with a distinct feature of water related soil erosion grouped with landslide scars. The soil erosion intensity classes were produced after a systematic segmentation of raster data from Soil-Adjusted Vegetation Index (SAVI) and Degraded Land Area (DAI) indices (83% total accuracy). Moderate soil erosion intensity class is better mapped with the help of the Leaf Chlorophyll Index LCI (99%).

For the pixel-based classification approach, a suitable level of accuracy is obtained by integrating multi-sensor (radar, optical, 10 resolution) and multi-date (all season data) input imagery, with an overall accuracy of 93% for the selected land cover, and 66% for the soil erosion class.

The output of the analysis can be a starting point for a specific product layer integrated within the spatial data infrastructure, needing periodic updating.

Keywords: erosion, land cover, classification, intensity, accuracy.

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**INTEGRATED LANDSCAPE MANAGEMENT
AND GOVERNANCE FOR BETTER REGIONAL
DEVELOPMENT POLICY**

How natural conditions in the Polish Carpathians do not affect spatial development

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Mountains, such as the Polish Carpathians, are particularly sensitive to spatial mismanagement. Since the international law (Carpathian Convention) was adopted for the entire Carpathian region two decades ago, trying to stimulate sustainable development, numerous application projects have been undertaken to develop and implement policies and guidelines for local governments for a better planning process. It turns out, however, that the problem of spatial chaos in the Polish Carpathians seems to be growing. This is especially visible in new buildings knowingly located in contradiction to the functioning of the landscape: on landslides, flooded areas and at high distances from the centres of villages (scattered buildings). Therefore, the question 'whether, and to what extent, spatial planning works preventively against wrong location decisions' arises. In order to answer it, a study was conducted within 238 Carpathian communities, where there were over 1,400,000 buildings. Using GIS techniques in the QGIS environment, the phenomena of locating buildings against natural conditions were examined, which was expressed in the formation of buildings on: (I) landslides, (II) floodplains, (III) slopes inclined above 10° , (IV) slopes with northern exposure and an inclination greater than 5° , (V) areas located above 700 m above sea level. The phenomenon of building dispersion was also investigated (VI). Next, the planning situation of communes, expressed in the percentage of coverage by local plans, was analysed. By using the Spearman's rank correlation, it was checked whether the good planning situation of communes limits inappropriate location. It turns out that only in the case of dispersed buildings, spatial planning can limit this phenomenon to some extent, but a very low value of the Spearman's correlation coefficient (r_s) = - 0213 may indicate that the strength of this relationship is weak and could be negligible.

Keywords: *the Polish Carpathians, spatial planning, spatial chaos, environmental conditions, environmental hazards*

Promoting a joint perspective for a better cooperation governance among Carpathians and the Alps – the Central Mountains project experience.

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The Alps and the Carpathians are part of a bigger mountain system. Mountains don't respect borders, as they are shared by many European countries. They claim specific needs and challenges that cannot be efficiently solved acting alone on a national/regional/local level. In various reports and territorial reviews, it is pointed out that new ways to work effectively between regions on transnational level are needed. This means looking beyond administrative boundaries to consider "functional" areas and to better understand the links between different types of territories. The Alps and the Carpathians are one of the most important natural corridors linking Central European countries. Despite their unique natural attractiveness, many of these territories are cross-border areas facing challenges related to strengthening territorial cohesion across borders, lack of a joint vision and effective cooperation, lack of finance, and lack of citizen involvement.

The "Central Mountains" project addresses the challenge of achieving a long-lasting, sustainable cooperation across borders in mountain areas through improved governance structures and processes that are critical for strengthening regional development and cohesion beyond borders. These structures for cross-border and transnational cooperation will support autonomous operation and continuous coordination, not working in the project cycles exclusively dependent on EU funding.

The main territorial challenges addressed by the "Central Mountains" project is the lack of effective cross-border and transnational cooperation in mountain areas. This cooperation is crucial, since it the basis for the proper management of natural resources, steering the sustainable development of the whole chain of mountain areas and ensuring that the local communities are involved in the process (including youth involvement).

Keywords: Cooperation, Cross-border, Governance, Carpathian, Alps, Carpathian and Alpine Convention

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Improving wolf-human coexistence in the Alps: first results from the assessment of socio-economic impact of the LIFE Wolf Alps EU project

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The LIFE WolfAlps EU project aims at guaranteeing the long-term conservation of the Alpine wolf population and at improving the wolf-human coexistence through a participatory approach. Concrete management actions must bear an impact on the ecosystem, both in ecological, social, and economic terms. Therefore, the project activated some activities specifically aimed at evaluating the usefulness and the success of the implemented conservation actions, to assess the impact of the project on the ecosystem and on the welfare of the local populations.

During the first year of the project a dedicated monitoring strategy was defined by the partnership. To be effective, this study was structured from the first year and gather data for the whole duration of the project. It had a strong coordination from a scientific point of view, ensuring that each partner reports periodically on the output and impact of their project activities. At the beginning, a set of socio-economic indicators was defined and agreed among the project team for each of the project actions. At the same time, also ecosystem functions indicators were developed, consulting the MAES guidelines (Mapping and Assessing Ecosystems and their Services). The quantitative assessment of the economic impact is complemented by an assessment of the social impact of the project. Authors aim at presenting and discussing the first results of the assessment of socio-economic impact of the LIFE Wolf Alps EU project; the acceptance and understanding of large carnivore projects by the public as well as key stakeholders, even in the Carpathians, depends on being able to demonstrate their added value with data and facts.

Keywords: *Wolf-human coexistence, Alps, socioeconomic indicators*

Combining system dynamics and decision trees for data-informed decision-making in mountain areas

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Mountain areas in Europe are experiencing environmental and socioeconomic changes, reshaping local human settlements and the landscape, and exerting pressure on biodiversity and natural resources. Achieving sustainable management in these areas requires a holistic understanding of current social-ecological processes and expected responses to future changes, all while considering the diverse perspectives of stakeholders involved.

This study focuses on the Southeastern Pyrenees, a region that has undergone a transition from agriculture to a tourism-based economy over the past century. This shift has promoted immigration, counteracting population decline, and urbanization of the region. Moreover, the already difficult issue of water availability is expected to further intensify due to climate change.

We propose a numerical approach that combines piecewise structural equation modeling, system dynamics and decision trees to assist in decision-making. Firstly, we use multidisciplinary mountain data to establish a network of relationships, forming the studied social-ecological system (SES). This enables the quantification of direct and indirect relationships among SES elements, offering insights into the system's current functioning. In a second step, the SES is modelled as a dynamical system to explore potential responses to variations in drivers of change. Finally, by analyzing simulation results, we can (I) gain further understanding of the effects of drivers of change (e.g., temperature) on SES elements; (II) assess how well different scenarios align with the values and priorities of different stakeholders; and/or (III) evaluate potential impacts of different development pathways on variables of interest. Therefore, we can evaluate the potential implications of the modeling results in a context-specific and inclusive way. In this presentation, we will outline the modeling process, present preliminary results, and discuss the potential application of this approach in other contexts.

Keywords: *social-ecological systems, sustainable local development, system dynamics, decision-making*

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Smart Village Mariiampil: Swiss-Ukrainian solutions on sustainability, community governance and industry recalibration for non-mountain Carpathian region of Ivano-Frankivsk oblast

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“Smart Village” concept has no legal definition within the EU legislation. However, the notion is well rooted into the world policies since 2016 Cork 2.0 Declaration for a Better Life in Rural Areas with 10-point manifesto for improving quality of life in rural areas. In 2017 the European Commission published EU Action for Smart Villages 3. Since 2020, DG AGRI has been implementing two of the European Parliament’s Preparatory Actions for smart Villages: Smart Rural 21 and Smart Rural 27. Through these official papers the Smart Village concept is associated with distinguished features such as participatory nature of community in improving economic, social and environment conditions, digital and innovative solutions, and design of sustainable strategies.

Both the Covid pandemic and the war in Ukraine have shown the rural areas in a new light, in need of a long-term vision by 2040 and with a focus not on problems, but potential. In this regard, a village of Mariiampil of 2807,40 hectares (areas) in Ivano-Frankivsk has a solid history of building on its resilience and local strengths to implement smart approaches. Furthermore, Mariiampil Development Strategy has vast opportunities to apply the UN 2030 Sustainable Development Goals, also an integral part of Ukraine’s recovery plan, into practice and daily life of its 751 inhabitants (incl. IDPs) and surrounding Dubivtsi territorial community.

The papers, developed within CAS Rebuild Ukraine project, aims to present the Smart Village Mariiampil vision as an instrument for the innovative and eco-friendly implementation of public tasks in rural area, in five following sectors: (1) land use change toward more sustainable and value added growing practices (2) IDPs reintegration, (3) energy independence (4) sustainable tourism based on local natural and historical resources and (5) vocational training and job creation. The presentation will include community-driven solutions and Swiss-Ukrainian expertise in each of the five areas, paving the way to scale up the project to the neighbouring regions in Ukraine.

Keywords: *Swiss-Ukrainian solutions, Integrated landscape management and governance for better regional development policy, socio-ecological transformations in the Carpathian Region, sustainable tourism, vocational education for sustainable development*

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Spatial differentiation of agricultural soils and their properties depending on selected morphopositional properties of the relief in the Liptovská kotlina basin, cadastre area Važec

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The paper focuses on the influence of morphopositional characteristics on the spatial distribution of soils in the cadastral area of Važec. Study area is a typical submountain village at the contact of the Liptovská kotlina basin and the Kozie chrbty mountain. At present there is predominance of forests and the low share of arable land and cattle grazing. The area has high potential for the development of rural and hiking tourism. Morphopositional characteristics have an important influence in the soil formation process and thus create room for the differentiation of soil types and their properties. The main thesis is to verify the relation of morphopositional properties on the soil properties such as soil depth and the strength of the humus horizon. It is assumed that in the concave parts of the slopes there are depth of soils with a deep humus horizon with sign of pseudo-gleying process. Convex landforms, on the other hand, have shallow soils with a weak to disappearing humus horizon. To create the basic analyses, such as slope and types of landforms we used the model of relief. Based on the results of the field probes, we create maps of soil types, soil depths, and humus horizon deep. By combining landforms, position and soil properties, we obtained results to determine the influence of landform morphology.

Keywords: *Soil types, Relief forms, Spatial differentiation of soil, Slope, Soil depth*

Acknowledgment: *This paper was supported by project APVV-17-0377 Assessment of recent changes and trends in agricultural landscape of Slovakia and VEGA 1/0342/22 Identification, evaluation and consolidation by erosion threatened hill lands in the lowland regions of Slovakia.*

Landscape ecological aspects of environmental quality assessment in the context of the health status of its inhabitants

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Environmental quality is a very important factor that affects the health status of the population and the very existence of living organisms. The research work is divided into theoretical and application part. The theoretical part is focused on the development of new landscape-ecological assessment approaches to the assesment of the quality of the environment, on the selection of relevant indicators, on the development of own assessment methodology, based on the evaluation of human activities and their impact on the landscape of its components and elements, and to find parallels between the quality of the environment and the health status of the population. In the application part, the theoretical experience are tested on model settlements of the Trnava district. The research included the implementation of a sociological survey. The aim of the sociological survey is to obtain the subjective view of the addressed sample of respondents on the assessment of the quality of the environment and its impact on the health status of the population. The results of qualitative and quantitative research will be used in planning and development documents at all hierarchical levels.

Keywords: *environmental quality, indicators, population, health, sociological survey*

What is the relevance of landscape audit in mountain landscapes for landscape research? a case study of the Western Beskid Mountains

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According to the European Landscape Convention (ELC 2006), European Union countries must carry out a procedure for identifying and assessing landscapes. The purpose is to protect landscapes of particular value and monitor the future condition of landscapes. In Poland, the implementing act of the ELC is the Regulation (2019), defining the procedure and scope of conducting a landscape audit at the level of municipalities, and its implementation is delegated to voivodship authorities.

In the presentation, the authors highlight the scientific and practical aspects of landscape audit results in the case of the Carpathian areas of Poland. The authors argue that this study may be one of the most important source materials for land management in mountain areas. The collected resources can be used in detailed studies, for example, at a scale of 1:10,000.

The Regulation defines a methodology for preparing a detailed database that combines information from several dispersed data resources. The collected datasets are partly derived from national databases (e.g. nature conservation areas, forest habitat types). However, a large part of this data was collected using expert methods of inventorying natural (e.g. valuable geomorphological objects) and cultural (e.g. state of preservation of traditional rural buildings) objects.

The landscape audit introduces new landscape units, whose boundaries should be based on physiognomic features and relates to physical-geographical regionalisation boundaries. In practice, most attention has been paid to land cover and less to landform features. The benefit of including land cover features is that the synergies of natural and cultural features visible in the landscape are included in the landscape units. The units obtained from the landscape audit can be considered as underlying spatial references for environmental databases, useful for further research.

Keywords: *landscape audit, Western Carpathians, spatial data base, European Landscape Convention*

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**PARTICIPATORY RESEARCH, MULTI-ACTOR
DIALOGUES AND KNOWLEDGE CO-
PRODUCTION**

Addressing Energy Poverty of the Marginalised Roma Communities: The Case of Lunik IX. Košice City-Ward

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The paper will present findings from an ongoing participatory action-based interdisciplinary research project, conducted in collaboration between RESDI – Roma Environmental Sustainability and Development Initiative, Friends of the Earth-CEPA, and the Municipality of Luník IX., Košice City-Ward, with an overall aim to develop and implement a municipal sustainable development strategy. The focus of the paper is on mapping of energy poverty of Roma communities in Luník IX., Košice, the largest urban settlement fully populated by Roma communities in Europe, and on the analysis of the potential to address it via the use of renewable energy sources. The issue of energy poverty recently grew in importance even more significantly due to rising utility prices as a result of the conflict in Ukraine.

The paper draws from secondary sources, primary data provided by the municipality, interviews and consultations with the mayor and field social workers as well as pilot energy audit data conducted at a selected building, Hrebendova 1-3 block of flats. This building was selected as it is owned by the municipality and a credit-based system of utility payments had been successfully implemented there. The paper begins by explaining the methodology, and presentation of the contextual analysis, which is followed by an analysis of the existing policy intervention, and subsequently by the results of the energy audit and the feasibility study, analysing of the available sources of funding for potential implementation of the interventions proposed by the auditors.

The study outlines several notable results. Firstly, the field-based findings on energy poverty, specifically access to utilities (water, electricity, gas), challenge the data available in the Atlas of Roma Communities 2019, highlighting that the access to these utilities necessary for basic quality of life are much lower than outlined in the Atlas of Roma Communities database. Secondly, the feasibility analysis showed that based on the existing public

funding schemes for renewable energy and the financial capability of the municipality and its residents, it is not feasible to implement renewable energy sources to improve access to utilities, and thus to address the energy poverty of the local community. The paper concludes by recommendations on the necessity of adjustments to the existing public funding schemes on the national level and on exploring the potential of establishing a community energy social enterprise on the local level.

Keywords: *Energy Poverty, Roma Communities, Slovakia*

Multi-disciplinary Approach for Inclusive, Competitive, and Green Economies and Societies in Mountainous Areas: The Experience of EU COST Action MARGISTAR

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Mountainous areas with their natural beauty and rugged landscapes, also pose unique challenges for the communities residing in these regions. Marginalization, economic disparity, and imbalanced use and conservation of ecosystem services are prevalent among mountain communities, including those in the Carpathians. To address these challenges and promote innovative solutions for a greener, digital future, a collaborative platform has been established within the EU COST Action MARGISTAR. It focuses on exploring the interrelationships and interactions among natural, environmental, social, and economic aspects in mountainous areas, bringing together diverse stakeholders, including scientists, policy makers, mountain actors, NGOs, SMEs, public bodies, and private organizations. This paper presents methods and approaches that facilitate collaboration between citizens and policymakers to achieve scientific, societal, and policy impacts and co-design innovative pathways towards their sustainable, digital, and healthy futures. By challenging conventional discourses and supporting e.g., the engagement of youth, using the innovative concepts of "pinching the policy maker" and "resilience erosion" it establishes a society-science-policy platform "Fairway in Europe", which fosters dialogue among stakeholders, including those in the Carpathian region. This presentation aims to foster collaboration between the Science of the Carpathian research network and MARGISTAR, strengthening efforts towards inclusive, competitive, and sustainable economies and societies. It emphasizes

knowledge exchange, co-creation, and capacity building opportunities. The paper highlights the importance of collaboration and cooperation between these initiatives to address the challenges faced by mountain communities and promote revitalization of marginalized mountainous areas across Europe to leave no one behind.

Keywords: *resilience, knowledge exchange, co-creation, capacity building and innovations, "pinching the policy makers" approach, platform "Fairway in Europe".*

Acknowledgement: *The paper prepared within EU Cost Action MARGISTAR - <https://margistar.eu/the-margistar-mission/>.*

Sustainable tourism development in marginal regions (Gemer-Malohont region, Slovakia)

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There are currently "corners of extreme poverty" on the territory of the Slovak Republic, which mainly occur in isolated rural areas and localities where the population is predominately Roma. The Gemer-Malohont region also once had the highest concentration of Roma people, but because of the territory's natural resources and its residents' talent, it was one of the most developed regions in Hungary. Now it is the poorest region in Slovakia. However, there are a number of tourism patterns that are founded on natural and cultural resources. There is potential for religious tourism at the Gothic Road sites. Karst relief and the mining-related sites and monuments along the Iron Road offer favourable circumstances for mining tourism and geotourism. Traditional agricultural landscapes can be found in the nearby communities, which provide favourable conditions for agrotourism. Literary tourism has great potential. The region has also options in lesser-known forms of tourism, such as ethnic tourism. Additionally, there is the interesting possibility of cross-border cooperation with Hungary. One of the current solutions for this marginal area is the coordinated development of these numerous forms of tourism. International trademarks are suitable for this purpose in this region as well as abroad. These trademarks include the Traditional Folk Culture Collection, the Center for Folk Art Production, the Industrial Property Office, and Council of Europe Cultural Routes, the Central List of Cultural Monuments, UNESCO Global Geoparks and the list of UNESCO World Cultural and Natural Heritage. These features collectively give the place a unique character and aesthetic.

Keywords: *Biodiversity, Geodiversity, Natural heritage, Cultural heritage, Intangible cultural heritage*

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Challenges and prospects of schools moving towards energy autonomy in the Ukrainian Carpathians

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Two reasons emphasize the urgency of energy saving and the transition towards using renewable energy sources in school buildings: 1) energy scarcity, high prices and unsatisfying heating situation; 2) the institution's social significance. Among all public institutions, on account of their educational purpose, schools have a significant social responsibility (Pereira et al., 2014), play an important role in ensuring sustainable development of the region and community well-being (Melnykovych & Soloviy, 2014) through education, and raise the level of environmental and social consciousness.

An analysis of the state of use of energy resources in educational institutions in Ukraine indicates that almost 81% are heated centrally, receiving heat from boilers operating on traditional fuel (i.e., natural gas and coal) (Karmazina, 2017). These numbers demonstrate the strong dependence of educational institutions on limited sources of fossil fuels. Their use continues to contribute to global warming. Ukraine has significant potential for renewable energy production among other Southeast European countries (IEA, 2023). Presently, 10.4% of Ukrainian renewable energy sources are in the Ukrainian Carpathians (Zhuk & Bashynska, 2016). However, they have been developed only to a small extent (Raslavicius et al., 2011; Child et al., 2017; Soloviy et al., 2019; Omelchenko, 2022; IEA, 2023).

In an effort to understand the problems, challenges and opportunities of moving toward energy autonomy of the Ukrainian Carpathians schools, and also best practices, this study explores the heating situation of these. To do so, a semi-structured questionnaire was developed, tested, and will be applied in face-to-face interviews with rectors, teachers, technical staff of the schools, persons in charge of the heating solution for the school buildings and parents of pupils. Survey data will be analyzed statistically and presented to key actors for school buildings' energy transition decision-making.

Keywords: energy transition, schools, forest-dependent communities, Ukrainian Carpathians, questionnaire survey

Acknowledgment: The investigation has been carried out within the project “Challenges and prospects of schools moving towards energy autonomy” (umbrella project: Cooperation in Forest Research Ukraine-Switzerland 2021-2024: Capacity building for improved forest conservation and management) supported by the Swiss Secretariat for Research, Education and Innovation (SBFI).

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PLASTIC IN THE MOUNTAINS

Roads as input zones of artificial macrolitter to fluvial system. The case of Kamienica Gorczańska stream in the Polish Carpathians

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Mountain rivers are a unique element of the ecosystem. They provide habitats for many species of plants and animals, provide water resources as well as play an important recreational role for human [1]. River valleys in mountainous areas, unlike the slopes, have a relief that facilitates the development of settlement and related transport infrastructure. This concentration of human infrastructure in mountain river valleys can favor waste emission. Plastic debris constitutes a part of the solid waste since the 1960s [2], and its input to mountain rivers is suggested to be particularly harmful because of high biodiversity and resources provided by these ecosystems for biota and human [3]. To evaluate importance of road's network as input zones of macrolitter to fluvial system, we have sampled macrolitter disposed along the different types of roads functioning in the floodplain area of the Kamienica Gorczańska Stream (Polish Carpathians). Our observations from 103 sampling sites located along the whole stream course, suggest that areas along the road is important entry points of macrolitter to fluvial system. The recorded locations of dumping sites suggests that, dirt roads leading directly to the river channel operate as point source of larger volume litter disposal. Asphalt roads located in river valleys more often function as zones of dispersed waste emission. We have recorded 1759 macrolitter items, including 845 (48.04%) macroplastics. Our results suggest that macrolitter disposal on river floodplain can be explained by spatial and functional pattern of road network in this area. We suggest that future management of roads in this area should be performed in the way that limits the possibility of dumping here (e.g., by restricting car access or video monitoring) and to facilitate removal of disposed litter before its mobilization by river water (e.g., by citizen science clean-up actions).

Keywords: *macroplastic, mountain stream, roads, household waste, waste management, Kamienica Gorczańska stream*

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First field experiment on plastic bottles fragmentation in mountain river channel

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River channel is a specific zone exposed to the constant transfer of water and sediments. These conditions can accelerate mechanical fragmentation of macroplastics being transported or stored in river channels, resulting in the production of smaller plastic particles (micro- and nanoplastics), which threaten biota and human health and are difficult to remove from the environment [1]. There is a lack of field-based quantification of this process, however our previous work has suggested that mountain rivers can be particularly effective in mechanical fragmentation of macroplastic due to its high energy flow and presence of numerous physical obstacles in the channel zone [2]. Here we report preliminary results from the first field experiment quantifying the rate of macroplastic fragmentation in mountain rivers. In 2022 we have placed 1-liter plastic (PET) bottles to the channel of the mountainous Skawa River in the Polish Carpathians. After 50–57 days of low-flow conditions, we have collected bottles ($n=47$) and determined their fragmentation rate as mass loss (g). Recorded fragmentation rates were non-normally distributed and reached for individual bottles from -0.0098 g to -0.1530 g (mean = -0.0827 g, SD = 0.04 g). Surprisingly, the fragmentation rates of bottles were not related to their travel distances, which reached from 0.4 km to 16.3 km during the experiment. Our preliminary results suggest a very wide range of PET bottles fragmentation rate. Considering the weight of used PET bottles (mean = 33.43 g) it can be roughly estimated they can be fully fragmented, in conditions represented by our experiment, in a time span ranging from 15 to 605 years, with the 30% from them estimated to be fully fragmented in less than 50 years. Our experiments suggest a high rate of mechanical fragmentation of macroplastic debris in mountain rivers occurring even during low-flow conditions. Future experiments should detail our estimation by the experimental data collected also during flood stages.

Keywords: riverine plastic, macroplastic fragmentation, secondary microplastic formation, mechanical fragmentation

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Mountains of plastic: Mismanaged plastic waste along the Carpathian watercourses

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Presence of plastic debris in the riparian zone of river creates numerous risks to the natural environment and human livelihood. To set the background for future evaluation of such risk in the Carpathian Mountains, one of the most biodiverse mountain areas in Central-East Europe, we utilised existing databases to map mismanaged plastic waste (MPW) along the 175,669 km of watercourses draining this region. We explored MPW levels as a function of altitude, stream order, river basin, country, and type of nature conservation in a given area. The Carpathian watercourses below 750 m a.s.l. (142,282 km, 81 % of the stream lengths) are recognized as significantly affected by MPW. Most MPW hotspots (>409.7 t/yr/km²) occur along rivers in Romania (6568 km; 56.6 % of all hotspot lengths), Hungary (2679 km; 23.1 %), and Ukraine (1914 km; 16.5 %). The Carpathian watercourses flowing through the areas protected at national level (3988 km; 2.3 % of all watercourses studied) have larger MPW values (median = 7.7 t/yr/km²) than those protected at regional (51,800 km; 29.5 %) (median MPW = 1.25 t/yr/km²) and international levels (66 km; 0.04 %) (median MPW = 0 t/yr/km²). Rivers within the Black Sea basin (88.3 % of all studied watercourses) have significantly higher MPW (median = 5.1 t/yr/km², 90th percentile = 381.1 t/yr/km²) than those within the Baltic Sea basin (median = 6.5 t/yr/km², 90th percentile = 84.8 t/yr/km²) (11.1 % of all studied watercourses). The MPW hotspots along the Carpathian watercourses mapped in this work can be seen as a potential base for targeting clean-up actions as well as manage rivers in the Carpathian Ecoregion in the future.

Keywords: riverine plastic, macroplastic, littering, Carpathians ecoregion, macroplastic hotspots

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Wood jams as hotspots of macroplastic deposition on mountain river

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The processes of macroplastic storage in mountain rivers is very poorly understood and it is unknown how different surface types of river areas affect it. In order to fill this gap, we investigated macroplastic storage on different vegetation covers and on wood jams in a channelized, single-thread reach and an unmanaged, multi-thread reach of the Dunajec River (Polish Carpathians). We found that exposed river sediments and herbaceous vegetation stored significantly lower amounts of macroplastic debris (0.6 and 0.9 g per 1 m²) than wooded islands and wood jams (6 g and 113 g per 1 m²). Wood jams stored more than 19, 129 and 180 times more plastic than those found on wooded islands, areas covered with herbaceous vegetation and exposed river sediments. Vegetated islands and wood jams covering 16.7% and 1.5% of the multi-thread reach stored 43.8% and 41.1%, respectively, of the total amount of macroplastic stored in that reach, whereas these surface types were practically absent in the channelized reach. On the other hand, the unmanaged, multi-thread reach, 2.4 times wider than the neighbouring channelized reach, stored 36 times greater amount of macroplastic per 1 km of its length. Our results proved that the storage of macroplastic debris in a mountain river is controlled mainly by channel management style and resultant river morphology. These processes are responsible for river hydrodynamics alterations and a longitudinal pattern of the zones of transport and retention of macroplastic during floods. We emphasize future research directions that should consider in more detail the role of wood debris in trapping and retention of macroplastic debris on mountain rivers.

Keywords: *Macroplastic storage, Mountain river, Wood jam, Wooded island, Channel morphology*

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Where does it trap? Plastic bottle accumulation hotspots detected by field experiment

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Information on macroplastic accumulation hotspots in river channels is of crucial importance for evaluation of environmental risks resulting from this pollution. It is also useful for planning clean-up actions in riverine environments. To detect hotspots of floating macroplastic accumulation on mountain rivers we have performed a field experiment utilizing tracked plastic (PET) bottles. We have placed 196 tagged 1-liter bottles to the channel of the mountainous Skawa River in the Polish Carpathians. After 50-57 days of low-flow conditions, we recorded the location of their deposition and travel distances ($n=64$). We have found that most of the tracked bottles were deposited on woody debris (71.9%, $n=46$) at elevations ranging from 0 to 1.2 m (median=0.4 m, quartile range=0.45 m) above the low-flow water level. Travel distance of tracked bottles were non-normally distributed and reached from 0.37 km to 16.27 km (median=1.73 km, quartile range=5.29 km). Surprisingly, the straight and narrow channelized reach of the studied river trapped 15.3 % of the plastic bottles transported through it, while the highly sinuous, wide unregulated one only 8.7 %, which is probably related to the more frequent contact of woody debris (present in both reaches) with the flowing water, occurring during low-flow conditions within the narrower, channelized reach. Our results confirm previous observation [1] suggesting that areas of woody debris deposition along mountain rivers can be a good indicator of macroplastic accumulation hotspots. Information on location of wood jams within the active channel zone of mountain rivers can support selecting of proper locations for river cleaning actions, and help in effective performance of such actions.

Keywords: *riverine plastic, macroplastic, littering, Carpathians ecoregion, macroplastic hotspots*

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MINI-SYMPOSIUM ON CARPATHIAN ENDEMIC SPECIES

Taxonomic diversity patterns in endemic plants of the Carpathian Region

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Biogeographic processes, which encompass the evolution of species in space and time, are exposed by current distributions. No other biological element has a more evident imprinting of biogeographical processes in its distribution pattern than endemics, i.e. species with a restricted range to a certain, well-delimited region.

The analysis of endemic species distribution may highlight not only their biogeography, but may also be used, through both the identification of taxonomic diversity hotspots, as well as rarity hotspots, as an indicator for prioritizing biodiversity conservation efforts.

Mountain ranges are recognized, along island archipelagos, as complex topographic systems that enhance evolutionary processes in their biotic component through habitat heterogeneity and isolation of distribution areas. In

Europe, the Carpathians are recognized as being both a center of biodiversity and an evolutionary hotspot (Mráz & Ronikier, 2016), including a rich endemic flora with 200 endemic or subendemic taxa (Bremán et al., 2020), but varying among different authors. Several previous studies have analysed the distribution or evaluated the list of endemic taxa at biogeographic level, thus stretching beyond the national view on endemism (Pawłowski, 1970; Tasenkevich, 1998; Kliment, Turis & Janišová, 2016; Mráz et al., 2016; Hurdu et al., 2016). However, the knowledge on distribution of endemics is still uneven across the Carpathians, due to both spatial detailing and taxonomic concepts.

We present in this talk an overview on current knowledge and future prospects on the distribution and taxonomic diversity of Carpathian endemics at different spatial scales, with an emphasis on the main aims and preliminary results of the initiative of the Carpathian Research Network Consortium, i.e. (I) overview of taxonomic variability and biogeographic concepts among different authors regarding the Carpathian endemics and subendemics; (II) distribution and centers of diversity of different categories of endemic plants at Operational Geographic Units level; (III) potential usefulness in biogeography, ecology and conservation research of an unified view on both taxonomy and distribution knowledge across the Carpathians at different spatial scales.

Keywords: *species distribution, centers of endemism, weighted endemism, vascular plants*

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The endemic flora of the Carpathians: towards better knowledge and efficient conservation of unique Carpathian biodiversity

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Endemic species, i.e. those restricted to a particular geographical region, are not evenly distributed in space. While some regions are poor in endemics, others feature high endemic richness, which reflects a complex biogeographical, ecological and evolutionary background. Because of their spatial limitation and biological significance, endemic taxa provide a meaningful proxy for assessing biodiversity hotspots and prioritizing conservation strategies.

Mountains are long recognized as particularly rich in endemics due to their spatial isolation and habitat heterogeneity. In Europe, the Carpathians are among regions with the highest endemic richness. Despite this widespread recognition, the knowledge of Carpathian endemics is still very fragmentary and contradictory. This is due to prevailing national level research which

largely conditioned taxonomic concepts and diversity assessments, neglecting phenotypic and genetic variation at larger, biogeographically meaningful spatial scales. To overcome this obstacle, botanists and evolutionary biologists from the main Carpathian countries established the 'Carpathian Research Network' to provide a platform for collaborative research focused on the taxonomy, distribution, evolution and conservation of endemic Carpathian flora based on a harmonized transboundary approach.

In this talk, we will outline the background and main achievements of this initiative, i.e. (I) standardized taxonomic list of Carpathian endemic and subendemic vascular plants; (II) standardized list of geomorphological units; (III) distribution database built on critically revised herbarium and literature records. We will also outline further steps planned to build a comprehensive information on the biology, ecology and phylogeny of these taxa. Finally, we will show how the collected data can be useful for conservation biology, delineation of protected areas or prediction of distribution ranges under climate change.

Keywords: biodiversity, conservation, endemism, protected areas, vascular plants

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A database and atlas of endemic vascular plants of the Carpathian Region

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High mountain ranges are known for their isolation and complex terrain, which often leads to a rich biodiversity including high numbers of endemic species. The Carpathian mountain range, with approximately 500 endemic vascular plants, is a recognized biodiversity hotspot in Europe. However, our knowledge of Carpathian endemics remains incomplete and contradictory, with fragmented and scattered data mostly handled at a national level, which hampers adequate understanding of this diversity and its use as a valuable proxy for recognizing regional diversity patterns and improved nature conservation and management. To address this issue, the 'Carpathian Research Network' has been working since 2016 with the aim of consolidating and developing botanical research at the scale of the Carpathians as a natural ecoregion (see also the introductory talk by Mráz et al. in this symposium). The

current main objective of this initiative is to gather and standardize data on the endemic vascular plants in the Carpathians. a shared database management system is a central part of this endeavour. The aim of this platform is to facilitate collaborative research on the taxonomy, distribution, evolution, and conservation of Carpathian endemic flora.

In this presentation, we will highlight the main achievements of this initiative, including a description of the database structure, a focalized overview of the main functionalities (i.e synonymy management with international taxonomies, data interoperability with existing databases, online distribution maps etc). Additionally, we will provide a preview of our online atlas, which will serve as a user-friendly interface for exploring, downloading, and analyzing the information.

Keywords: database management, biodiversity atlas, conservation, endemism, vascular plants

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Intraspecific diversity and differentiation of the Carpathian endemic plants: identification of diversity patterns at various spatial scales for natural heritage knowledge and conservation

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Biodiversity encompasses several functional levels including intraspecific, species- and community-level diversity. Intraspecific level defines the genetic structure of a species' populations and is most directly relevant to its response and resilience to environmental changes and microevolutionary processes. Hence, it is one of key aspects for understanding the biogeographical history of the regional flora, and consequently for an optimal management and conservation of natural resources. The Carpathian Research Network is a scientific initiative which aims at development of comprehensive botanical research internationally harmonized across the entire Carpathian ecoregion

(see also the contribution by Mráz et al. in this symposium). The current focus of the CRN activity is on the Carpathian endemic flora, which defines the unique element of the regional diversity. Along with setting a standardized taxonomic, geographic and chorological framework and gathering basic distribution data for endemic taxa, one of main endeavours of the Network is to gain a possibly comprehensive insight into the evolutionary history of this flora including the genetic structure of species. In the presentation we will briefly outline, based on hitherto available case studies, the patterns of genetic structure of selected endemic plants at various spatial scales (from the entire Carpathian arch to single mountain massifs, such as the Tatra Mts.) and their implications for better understanding the evolution and biogeography of the endemic flora. As further perspective, we will also highlight further plans to use molecular tools for efficient screening and monitoring the Carpathian plant biodiversity.

Keywords: *Diversity patterns, Genetic structure, Phylogeography, Vascular plants*

CLIMATE CHANGE 1

Predicting Thermal and Precipitation Extremes in the Carpathian Region: a Machine Learning Approach

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Extreme weather events have become more frequent in recent years (IPCC, 2021). Due to complex topography and synoptic airflow, the Carpathian Mountains region is highly susceptible to thermal and precipitation extremes. This study aims to utilise machine learning techniques for predicting daily thermal and precipitation extremes in the Carpathian region. The objectives include evaluating the performance and identifying the importance of seasonal, geographical, and synoptic drivers. This study is based on minimum, maximum temperature and total daily precipitation from the CarpatClim project dataset (1961–2010) covering latitudes 44°N to 51°N and longitudes 17°E to 28°E with 0.1°x0.1° spatial resolution (5895 grid points). Geographical variables (elevation, latitude and longitude) and synoptic airflow indices (strength, vorticity and direction) were incorporated. The generalised extreme value (GEV) distribution was utilised to depict the intensity of extreme thermal and precipitation occurrences as it has a universal function in describing block maxima (Coles, 2001). This function is inspired by the extreme value theorem or Fisher–Tippett–Gnedenko theorem (Fisher & Tippett, 1928; Gnedenko, 1943) and was extensively used in climatology and hydrology. Ensemble models, particularly Extreme Gradient Boosting algorithms, were utilised, and Bayesian Optimization (Garnett, 2023) was employed for hyperparameter tuning. The study provides insights into the potential of machine learning for prediction, achieving root mean squared error values ranging from 0.66 to 2.54 (Skrynyk, 2023). Relative importance analysis reveals the significance of various drivers. Spatial and temporal factors and atmospheric circulation patterns are highlighted for predicting extreme events. This study enhances our understanding of climate dynamics and offers practical implications for improving forecasting and warning systems for cold and heat waves, floods, and landslides in the Carpathian region.

Keywords: *machine learning regression, extreme gradient boosting, Bayesian optimisation, generalised extreme values distribution, CarpatClim*

Acknowledgement: *I immensely thank Nita I. from Meteo Romania (pers. comm.) for providing data on airflow indices derived according to Micu et al. (2021), following the methodology by Jenkinson & Collison (1977).*

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Extreme precipitations statistics for the alpine treeline ecotone in the High Tatra Mountains, Slovakia

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Mountain areas are prone to natural hazards and risks when extreme precipitation events occur. Although future rainfall extremes are projected to increase with global warming, common (annual) and rare (decennial or centennial) extremes could be affected differently (Gründemann et al., 2022).

Alpine treeline ecotone (ATE) is strongly controlled by climate and also by land-use practices. A long-term climatological dataset obtained at Skalnaté Pleso Observatory enables us to perform an analysis of precipitation extremes for the southern slopes of ATE in the Slovak part of the High Tatra Mountains.

In this work, daily precipitation data were used for the calculation of extreme precipitation indicators defined by the Expert Team on Climate Change Detection and Indices (ETCCDI) and Extreme Value Analysis (EVA). Indicators for the last normal period (1991–2020) were referenced to the previous (1961–1990) and to the long-term period of 1946–2021 including an absolute daily rainfall maximum of 170 mm in June 1958.

Results show a decrease in maxima for both 1-day precipitation and 5-consecutive precipitation days. Estimation of rainfall return levels with parameterization (Onderka and Pecho, 2022) suggests that the historical daily rainfall of 170 mm can occur approximately once every 250 years. Based on the decrease of the indicators above, the assumption of increasing precipitation extremeness was not confirmed.

On the contrary, an increase in indicators such as the number of wet days, the maximum number of consecutive rainfall days, frequency of 1-day precipitation over 20 mm, and values of 90th, 95th, and 99th percentiles means the occurrence of longer and more intense rainfall events during the last decades. These events are potentially dangerous and can cause flooding in the Carpathians (Wypych et al., 2018).

Keywords: *rainfall daily maxima, extreme value analysis, return level, natural hazard, flooding*

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Slovak Hydrometeorological Institute for the data they measure at Skalnaté Pleso Observatory.

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Assessing the vulnerability to the diminishment of snow coverage in mountain snow tourism destinations. First findings from the Interreg Alpine Space project "BeyondSnow".

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Many snow tourism destinations at low and medium altitudes (STDs), and their communities are experiencing the reduction in snow cover. Damm et al. (2017) estimated that Europe could lose up to 10 million ski tourism-related overnight stays per winter in the upcoming years. The Alps have witnessed a 2°C temperature increase since the early 20th century, leading to a significant decrease in snow cover and a shorter snow season (38 days between 1960 and 2017, according to Jeffrey Kluger - Time), along with increased costs for snowmaking.

Apart from the ecological consequences, these STDs at low and medium altitudes must also consider socioeconomic impacts, including a gradual decline in the number of skiers and a reduction in the average length of stay. Recent censuses on the viability of ski destinations in the Italian mountains reveal a complex situation, with a growing prevalence of abandoned or financially dependent facilities relying on public funding. Despite being a significant pillar of mountain tourism in the past, the sector continues to provide employment opportunities for many individuals and supports the economies of various communities and tourism destinations.

To address these challenges, a transition to new, sustainable models of tourism development is necessary. These models should prioritize the preservation and enhancement of territorial assets, offering unique tourism experiences rooted in local natural and cultural heritage. The Interreg "Alpine Space" project "BeyondSnow" aims to explore and promote such models. The authors plan to present the initial findings of the project and discuss them at the 2023 Forum Carpathicum. The presentation will focus on analyzing the relationship between past, current, and future climate change-induced reduction in snow cover and the potential socioeconomic effects on mountain STDs. The vulnerability and resilience of these destinations will also be examined.

Keywords: *Climate Change, Alps, snow cover, impacts, vulnerability, snow tourism destinations*

Snow cover response to temperature and precipitation variability in Polish Carpathians

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Mountainous areas are uniquely susceptible to climate change, making them good indicators of these changes. Research results from different parts of the world indicate recent warming of mountainous regions, particularly located since the 1980s, with different intensity in particular vertical zones. Temperature growth is not followed by significant trends in annual precipitation totals however it brings the change in precipitation annual structure and types what influences the occurrence and persistence of snow cover.

As snow cover is a key element of the Earth's system with the impact on hydrology, climate, and ecological environment any changes in snowpack patterns will have a complex effect. The aim of the study is to examine the variability of snow cover variables (snow depth and snow cover duration) and they sensitivity to the main atmospherical drivers (temperature and precipitation) including inter-annual variations, and trends over various time scales.

The research has been conducted for the Polish Carpathians. The analyses cover the period 1981-2022 and are based on various meteorological data sources, i.e. in-situ snow depth observations and near ground temperature and precipitation measurements (serving as reference data) as well as regional reanalysis ERA5-Land.

The primarily research results confirm the significant impact of temperature and precipitation change on snow cover characteristics with the differentiation of its intensity dependent on geographical and terrain variables as the altitude, landform, slope and exposition. Nevertheless multiannual variability of snowpack persistence with its decreasing trend over the whole research area has been observed.

Detailed understanding of the timing of snow accumulation and snow ablation is necessary as it controls the mountain runoff rate during the spring, water infiltration and groundwater storage as well as the transpiration rate, crucial elements of hydrological cycle.

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Should we worry about what the future holds for us in terms of rainfall extremes?

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Heavy rain pouring down rapidly over short periods of time can trigger flooding if it provides more water than the ground can absorb. Rainfall frequency estimates, mathematically represented by Rainfall Intensity-Duration-Frequency (IDF) curves, are used to express the relationships between rainfall intensity, rainfall duration (aggregation scale) and the frequency of occurrence (probability). To account for the changing climate, rainfall frequencies for the Western Carpathians and the adjacent lowlands were estimated using the non-stationary concepts of the extreme-value theory. Our goal was to estimate exceedance probabilities for rainfall intensities with durations ranging from 5 minutes to 180 minutes. Several Regional Climate Models (RCMs) with a spatial resolution of 0.11° were used to give an insight into the future of short-duration rainfall extremes. We used the EURO-CORDEX 3-hr precipitation products simulated by three RCMs: DMI-HIRHAM5; SHMI-RCA4; KNMI-RAMO. The lateral and lower boundary conditions to the RCMs were defined by the Global Climate Model (MOHC-HadGEM2-ES). In our preliminary analyses we focused on three emission scenarios (RCP 2.6, 4.5 and 8.5). Maps displaying the future rainfall frequencies have been created for the high-emissions scenario (RCP 8.5), which corresponds to 8.5 W/m^2 forcing across the planet and a temperature increase of about 4.3°C by 2100 (relative to pre-industrial temperatures). a novel bias-correcting method based on quantile mapping and non-stationary EVA has been developed. Since sub-hourly rainfall intensities are important for hydrological modelling in urban areas, rainfall intensities with durations <180 minutes were estimated by applying empirical scaling functions. Our simulations suggest that by 2080, rainfall intensities (100-year return period) may increase by up to $\sim 10\text{--}20\%$ compared to the reference period 1991–2020 (RCP 8.5 scenario).

Keywords: rainfall, intensities, IDF curves, EURO-CORDEX, RCM, climate change, urban hydrology

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The monitoring of drought in the Ponitrie Protected Landscape Area from 2018 to 2022 with MODIS Land Surface Temperature

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Drought, a natural phenomenon that occurs at multiple time scales and affects large areas and every part of the hydrological cycle, is a recurring extreme event causing great harm to not only agricultural production but also society and protected areas. Owing to global warming, droughts have been occurring more frequently over expanding areas in recent years. Therefore, monitoring drought and studying its spatiotemporal dynamics are important for improving protecting the environment, and promoting sustainable social economic development. In recent years, the use of remote sensing data has proven to be an effective tool for monitoring drought conditions. This study focuses on the monitoring of drought conditions in the Ponitrie Protected Landscape Area from 2015 to 2022 with MODIS Land Surface Temperature. By utilizing MODIS data, the study aimed to assess and track the extent and severity of drought events in the landscape area. The analysis provided valuable insights into the spatial and temporal patterns of drought, enabling a comprehensive understanding of the area's vulnerability to water scarcity. The results of this study contribute to the scientific understanding of drought dynamics in the Ponitrie Protected Landscape Area and can aid in the development of effective drought mitigation and management strategies for the region. Remote sensing data provides several advantages for monitoring drought. It allows for the collection of frequent and consistent measurements over large areas, providing a comprehensive view of drought patterns. The use of remote sensing data enables the study to capture the thermal dynamics of the landscape, which are closely related to drought conditions and provided valuable insights into the spatial and temporal patterns of drought, enabling a comprehensive understanding of the area's vulnerability to water scarcity.

Keywords: *Drought, Modis, Landsurface temperature, Ponitrie Protected Landscape Area*

Acknowledgment: *This research was supported by the Integrated Infrastructure Operational Programme funded by the ERDF, project ITMS2014+ 313011W580, "Scientific support of climate change adaptation in agriculture and mitigation of soil degradation", and by the Slovak Scientific Grant Agency VEGA 02/0115/21 "Long-term changes of atmospheric pollution and their impact to ecosystems."*

LAND USE AND LAND COVER CHANGE 1

Monitoring forests from illegal logging in Ukraine for 2020– I quarter of 2023

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Based on the summarizing the research conducted by experts of the NGO "Forest Initiatives and Communities" (ForestCom) during 2020 – I quarter of 2023 to verify compliance with forestry rules and legislation by forest users, documented during field surveys in forests in different regions of Ukraine, and within cooperation with law enforcement agencies and other regulatory authorities to prevent illegal timber trade on the domestic and foreign markets, as well as the results of monitoring of related criminal proceedings and court cases conducted a monitoring of illegal logging in Ukraine.

During the specified period, ForestCom experts surveyed 148 forest sites/ or groups of sites in 9 regions of Ukraine, with a total area over 2,900 ha, in which 315.3 ha of cutting areas were checked. The experts revealed signs of forest violations of varying degrees of importance and submitted 23 statements to the territorial bodies of the State Environmental Inspectorate on their base, ten statements were submitted for investigation to the State Bureau of Investigation, nine – to National Police. 21 cases of loggings were identified, which had all the signs of illegality at the time of detection, according to which losses totaling UAH 4,014.413 thousand were accrued. Based on the results of the facts about forest violations revealed during field surveys, a total of 12 criminal proceedings were opened, one was closed due to insufficient evidence, and one was positively considered in court.

During the reporting period, ForestCom experts conducted 47 expert studies within criminal proceedings on illegal logging, customs regulations and other laws of Ukraine related to illegal wood trade in 5 regions of Ukraine.

Keywords: *forest ecosystem, remote sensing, forest violations, forest cover losses*

Acknowledgment: *The investigation has been carried out within the project "Combating illegal logging in Ukraine" with the support of the International Programs of the US Forest Service.*

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Legacy of the past in the Skalica district

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Human activity strongly influenced landscape of Skalica district. As favourite hunting grounds of Austro-Hungarian nobility, local forests gained their "net structure" and alleys of trees were planted along the streets heading to manors. Manors had their own ornamental gardens. Viticulture has a long tradition in hilly parts of the district and to these days there are managed vineyards. Area had a dense network of small, unregulated watercourses. Due to regular floods, soil along the Morava River was waterlogged, making it impossible to use these areas for agriculture. Over time, some ornamental gardens were repurposed or abandoned. Watercourses have been regulated, some waterlogged areas partially or completely drained and often turned into arable land or pastures. The greatest transformation of landscape took place in the 1950s during the period of collectivisation, when small plots of arable land were united into large blocks. This period also marked the beginning of construction of panel housing in towns. This led to an increase in the numbers of urban residents and expansion of the build-up area. Recently, the most significant trends in landscape change have been urbanisation and the abandonment of mainly agricultural land or industrial areas.

Keywords: *Land cover Change, Urban Landscape, Green infrastructure, Skalica, Historic Landscape*

Acknowledgment: *This research was supported by the project VEGA 2/0011/21 "Landscape-ecological aspects of green and blue infrastructure in creation of an optimal spatial basis for ecologically stable areas in urban landscape."*

Mapping of land cover changes in the regions of Ukraine with application of the Corine Land Cover methodology

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The drastically changing climate requires implementation of new approaches to control land use changes in order to be aware of the impact development has on ecosystems. It is useful for modeling possible future scenarios and defining to what kind of emergencies an area is prone to.

In 2019 Ukraine took part in the CORINE Land Cover (CLC) [1] ENI SEIS II East Project with the pilot area chosen around Kyiv. This activity was an important step to facilitate the access to, and use of, spatial data required for SEIS implementation at a national level.

In May 2023 the second part of the project has started. The AOI was delineated within Ivano-Frankivsk and Zakarpattia oblasts in order to define land types and trace the land cover changes.

Materials and methods. Mapping methodology is based on the CLC methodology. In order to produce status and change layers the imagery data from the Sentinel-2 satellite is used. The images are chosen for spring – autumn period to have the full understanding of the land types and be able to classify them precisely according to the national nomenclature

The change layer is produced by gradually going through the status layer put over the satellite image from the spring – summer period of an earlier year.

Results. The maps for 2005, 2018, CLC changes (2005–2018) were acquired during the first part of the project (Fig. 1). It is expected to map the Ukrainian Carpathians region in the same manner by the end of 2023.

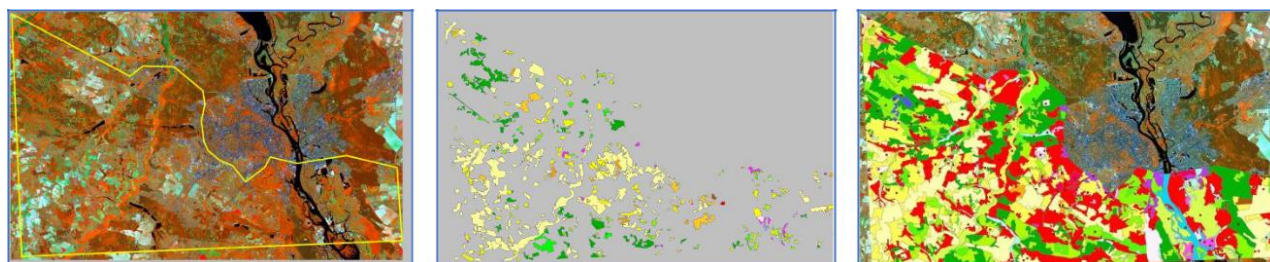


Figure 1. Sentinel-2 cloudless mosaic (June 2018) of the AOI (left), change layer 2015–2018 (center), status layer 2018 (right)

Keywords: *Corine Land Cover, Ukrainian Carpathians, land use, land cover, land change.*

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Land use-related threats and risks affecting the biodiversity-rich grasslands in the Alps and the Carpathians

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Biodiversity-rich grasslands are among the most threatened ecosystems in the mountains of Europe. They are often located in areas where they are not climax habitats, meaning that without human intervention they will disappear. However, due to socio-economic changes in many mountain areas, we observe dynamic changes there in land use, and management practices, which makes the existence of grasslands uncertain. In this work we want to list the main land use-related threats affecting the biodiversity-rich grasslands located in the Alps and the Carpathians, referring to the differences in biophysical and socio-economic conditions of the regions. We identified the main proximate causes and underlying driving forces of land use change affecting the grasslands (Geist, Lambin, 2002), in order to define the effective measures of protection in future. Our results show that in the context of land cover and land use conversions the main threats are connected to abandonment of agricultural practices leading to secondary succession, which is a result of processes that vary largely across the space. For instance, in the Carpathians, job opportunities outside agriculture are identified as one of the main drivers of land abandonment. Locally, however, the situation is more diverse. E.g., in Poland, land fragmentation due to ownership patterns, is an important driver of grassland loss, while in Slovakia high risk is related to the conversion of grassland to settlement, especially in the attractive sites. In the Italian and Austrian Alps, rural out-migration or high labour requirements for management due to less favourable biophysical factors play an important role as the abandonment drivers. When considering land use modifications, the problem of intensification of the grasslands management in the Alps seems more dominant than in the Carpathians. At the same time in the Carpathians,

improper management practices and lack of consideration of a wide range of ecosystem services delivered by grasslands seems to be an important threat.

Keywords: *grasslands, biodiversity, land use change, the Carpathians, the Alps*

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CONSERVATION AND SUSTAINABLE USE OF BIODIVERSITY 1

General policy orientation change from agriculture to rural development: family-based entrepreneurship in mountainous regions of Georgia

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In recent years, there has been a shift in policy focus from agriculture to rural development, which has created opportunities for rural families to diversify their economic activities. Household-based resources are essential for capitalizing on newly available opportunities. Locals with sufficient resources seize possibilities in agriculture and emerging economic sectors such as tourism (Gugushvili et al., 2021).

The research focuses on the transformation of family-based entrepreneurship engaged in tourism, agriculture, and other non-agricultural activities in three mountain municipalities of Georgia, Kazbegi, Khulo and Mestia. Research asks two main questions:

In what ways do households obtain various forms of capital (eg human, social, financial, etc.)?

How do families capitalize their resources to initiate new entrepreneurial activities or enhance current ones?

Locals in rural regions are portrayed as resistant to contemporary farming practices and technologies. Contrary to common opinion, research revealed that rural households had embraced new crops and farming practices. Households are motivated to participate in and adopt modern farming methods. The activities diversify their income and adapt to changing market demands and customer preferences. Along with incorporating current agricultural practices, locals use traditional techniques. Households employ traditional knowledge to engage in entrepreneurial tourist activities in addition to long-established industries. The skills that are part of the locals' way of life, such as hosting guests, cooking, and crafting, become invaluable tools for launching a family business in tourism. Local families have the chance to learn cutting-edge skills at educational institutions, participate in brief theme-focused teaching, and blend this knowledge with unique practices, resulting in a distinctly local tourism product (Gugushvili et al., 2019).

Keywords: Capital, resources, family-based entrepreneurship, inequality, mountain

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Hotspots of the Habitats Directive species and habitats in the Carpathians

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The knowledge on species and habitat distribution is crucial for their protection and this was our motivation to study Carpathian distribution of species and habitats listed in annexes of the Habitats Directive. As data source we used reports submitted by the EU member states according the Habitats Directive Article 17 in 2019, therefore Ukrainian and Serbian part of Carpathians was not included. We registered high number of species of Community importance in Hungarian part of Carpathians, adjacent part of Slovakia, in SW outcrops of Carpathians at SK/AT and CZ/AT borders. We suppose, mixing of Carpathian and Pannonian species plays role in these territories. Individual taxonomical groups exhibit different patterns. While mammals and partially also invertebrates follow the general species pattern, amphibians and reptiles show even larger areas of cells with high number of species in Hungarian Carpathians and quite high numbers in Czech Carpathians as well as in Transylvanian plateau and Apuseni Mts. in Romania. The hotspots of fish distribution are located in the Southern Carpathians along Danube and Mures rivers in Romania and in Transylvanian plateau. High numbers of plant species were reported from Polish Carpathians and individual cells with high number of plant species are scattered through Slovak and Hungarian Western Carpathians.

The number of habitats per grid cell is generally higher in Western Carpathians and the highest numbers were reported from high parts of Western Carpathians. The hotspots represent High Tatra/Western Tatra Mts. (both Polish and Slovak parts), Malá Fatra and Veľká Fatra Mts., followed by Small Carpathians and parts of Low Tatra/Slovak paradise/Muránska planina Mts.

We analysed how these hotspots are covered by Natura 2000 sites and provided recommendations.

Keywords: *nature conservation, Natura 2000, species and habitat distribution,*

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Soil mite fauna as bioindicator for ecological assessment of some grassland ecosystems from Romanian Carpathians

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Permanent grasslands cover 34% of the European Union's agricultural area (Vannoppen et al., 2023). The main threats of them are afforestation, abandonment of semi-natural grasslands and increased management intensity. All these threats lead to biodiversity loss and a decline in ecosystem services and functions (Schils et al., 2022). The study proposed to highlight the impact of management type from some grasslands from Romanian Carpathians, on soil mite communities. The study was accomplished in August 2018, in four grazed grasslands (by sheep) and four ungrazed ecosystems. The study took into consideration the complex influences of environmental variables on these soil invertebrates, as: vegetation coverage, air temperature, air relative humidity, soil temperature, soil moisture content, soil electrical conductivity, soil acidity and soil penetration resistance. The values of studied environmental parameters differed significantly between grasslands. The ungrazed grasslands were characterized by the highest values of air temperature, soil acidity, soil electrical conductivity, soil resistance at penetration and vegetation coverage. The grazed ecosystems were identified the highest values of air relative humidity, soil temperature and soil moisture content.

Quantification of structural parameters of soil mite communities, revealed that in ungrazed grasslands number of species, number of individuals, Shannon index of diversity, Simpson index, evenness and equitability indices recorded higher values in comparison with those from grazed ecosystems. Using a multivariate analysis we demonstrated that the management type and investigated environmental parameters, creates different structural composition of soil mites' communities. Soil resistance at penetration played a leading role in affecting the distribution of the mite community, followed by vegetation coverage and soil electrical conductivity. Anthropogenic disturbance influence negatively the soil fauna communities.

Keywords: environment, grazing, invertebrate, soil, structure.

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Nurturing the Future of the Carpathians in a Time of Critical Transition: Exploring Triggers for Sustainability in the Post-War Era

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The ongoing war in Ukraine has had devastating consequences, resulting in a significant loss of life and the displacement of millions of people. The Carpathian region has emerged as a refuge for war-displaced Ukrainians and a crucial center for providing humanitarian aid during this time of conflict. However, the Carpathian region now faces increasing challenges, including mounting pressure on its natural resources. This study focuses on the critical transition taking place in the Carpathians and explores the role of social innovations and capacity building initiatives in facilitating this process. By analyzing the impact of the war on the region, considering both economic losses and environmental damages in Ukraine, we uncover the immense potential of social and socio-ecological innovations to trigger sustainability and address the challenges faced by the Carpathian region during this crisis. Collaboration among stakeholders, including universities, civil society, and governments, can play a vital role in promoting sustainable land management practices, facilitating ecosystem restoration, and establishing initiatives such as green job opportunities and circular bioeconomy models in trans-border settings. Additionally, the findings highlight the valuable prospects offered by social innovations in creating livelihood opportunities and implementing robust social support systems for war-displaced people in the region, such as through the implementation of capacity-building advanced training programs like the one launched in Switzerland, "CAS Rebuild Ukraine". Integrating social innovations in decision-making processes and fostering capacity-building initiatives can alleviate pressures on natural resources, mitigate conflicts arising from competing interests, and foster inclusive and sustainable development within the Carpathian region. Furthermore, by embracing sustainable practices and empowering local communities, Carpathian countries can pave the way toward building a resilient and prosperous future for the region. By harnessing the power of collaboration and embracing sustainable solutions, the region can forge a path toward resilience and prosperity.

Keywords: *Socio-ecological innovations, CAS Rebuild Ukraine, sustainability in nature use and ecosystem services, multi-actor collaboration, war-related challenges*

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Factors influencing cultural ecosystem services and disservices

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Cultural ecosystem services (CES), defined as the contributions that ecosystems make to human well-being in terms of identities, experiences and capabilities, are generated by the interaction between the environmental spaces, human perception and activity undertaken in this space (Fish et al. 2016). Consequently, three groups of factors influence the perception of CES, i.e., biophysical and spatial characteristics of these spaces, social and personal factors related to the observer, and the type of interaction with nature. CES are one of the main reasons for ecosystems conservation (Chan et al., 2012), and at the same time they shape to a huge extent the landscape planning policy, while other drivers, e.g., production aspects, lose priority (e.g., Plieninger et al., 2012). Furthermore, disservices (EDS), understood as harms to people from human-ecosystem relationships, are also important factors for managing green spaces (Lyytimäki and Sipilä, 2009).

The aim of the presentation is to provide insights on the influence of different factors on delivering CES and EDS. The examples come from the studies conducted in different green spaces, i.e., mountainous area (Pieniny Mountains, Polish Carpathians) and urban area (Kraków, Poland). The applied methods included online survey, onsite survey as well as semi-structured interviews. The results showed that all analysed green spaces provided CES to a certain extent. However in the case of specific CES and EDS particular landscape features play important role. In terms of plant community the most species-rich plant community provides the highest flow of inspiration and education value whereas strengthening social bonds is similar independent of plant community. Also social characteristics such as gender, age and place of residence had significant influence on CES and EDS perception. The personal factors influenced the most perception of spiritual values and strengthening social bonds.

Keywords: *Kraków, Pieniny Mountains, semi-natural grasslands, urban green space, landscape features*

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Carpathian Quality System for Grass-Fed Beef

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The growing awareness of consumers and the demand for food with high nutritional and health-promoting value became an inspiration to develop and implement a new regional food Quality System called "Carpathian Pasture Beef". It assumes that cattle should be handled as closely as possible to the natural lifestyle of ruminants, in which pasture is the basis of nutrition. Meat obtained in this way is referred to as "grass-fed beef" (Shinn and Pledger, 2023). Production based on agro-ecological principles of environmental, economic and social sustainability may ensure profitability and high product quality, increase animal welfare, improve the stability of agrocenoses, preserve and even increase biodiversity, protect soil against erosion and improve its fertility, protect water, mitigate climate change by reducing the carbon footprint, increase the diversify of agricultural production and tourist attractiveness of the countryside. These goals can be achieved by applying the so-called regenerative agriculture, aimed at reversing the depletion of natural resources caused by intensive farming (Moyer et al., 2020). It is planned to use appropriate agricultural techniques (including intensive rotational grazing, agroforestry) and cattle breeds, as well as to maintain the highest standards in transport and slaughter of animals and cutting beef carcasses. The implementation of the System will include: development of beef quality, branding and certification standards, consultations with consumers, farmers and industry organizations, trainings for farmers on System assumptions, carcass cutting, processing and direct sales, development of marketing strategy, website creation, facilitating access to markets for farmers participating in the Quality System - logistics support, opening shops and stands at local markets. The System of "Carpathian Pasture Beef" can contribute to the ecological restoration of Carpathians grasslands, climate protection, increased profitability of small and medium-sized local farms, and meeting the needs of the most conscious and demanding consumers.

Keywords: grass-fed beef, agroecology, regenerative agriculture, regional food quality system, Carpathian Pasture Beef

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CLIMATE CHANGE 2

Climate change in the Carpathian forests: recent developments

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The review study presents the effects of climate change on Carpathian forests based on a literature search in the Web of Science and Scopus databases, resulting in 276 relevant papers. Climate warming (in combination with land-use changes) are considered to cause various responses of forests, such as an extension of the vegetation period, changes in wood production, shifts of treelines, bark beetle calamities or limitations in tree water relations. These responses may interfere, as e.g., rising temperatures lead to an earlier bud break and the prolonged vegetation favours wood production upslope. Also, changes in precipitation patterns and extreme droughts affect trees directly, whereas stressed trees are also more vulnerable to biotic attacks (e.g., bark beetles, fungi). Among the Carpathian forest species, Norway spruce is highly susceptible to climate change. It exhibited increased variability in radial growth in many areas, and heatwaves and droughts were found to substantially reduce growth rates. Fir species are overall less susceptible than spruce, but different lineages demonstrate varying responses. Beech forests are more affected by drought than heat, with decreasing summer precipitation posing a challenge in low-mountain regions. Oaks exhibit high adaptability, but severe and prolonged droughts make them susceptible to fungal attacks.

Keywords: *climate change, Carpathian forests, vegetation period, tree water relations, species-specific responses.*

Silvicultural approach required to increase forest resilience to climate change and wildfires in the Ukrainian Carpathians

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The four oblasts (regions) affiliated with the Ukrainian Carpathians (Lviv, Ivano-Frankivsk, Zakarpattia and Chernivtsi) represent 9.3 % of Ukraine's territory and contains 22 % of the country's forest lands (SFRAU, 2023). Forest cover in the region has changed relatively little over the last decades and slight increase in forest area is observed (Forest of Western Administration, 2023; Myroniuk et al., 2022, Tkach, 2012). Over the last 4 years, among 15.9 million m³ of logged timber, 6.2 million m³ (40 %) has been harvested in mature stands. Clear-cuttings carried out on 46.9 % of the area. Only 41.2 % of the wood is suitable for commercial purposes, others are determined as firewood. Moreover, 2.1 million m³ have been logged as part of sanitary cuttings (Forestry Innovative Research Centre, 2023).

In 2022 wildfires covered a total area of 61.5 thousand hectares (2.9 thousand cases): in Ivano-Frankivsk (11 064 hectares), Zakarpattia (12855 hectares), Chernivtsi (2 885 hectares) and Lviv (34 677 hectares) oblasts. It is observed that 93 % of the area of all fires occurred in March, where 7 % are forest fires (REEFMC, 2023). Over the last 30 years, the Carpathian region was not affected by large scale forest wildfires, however in 2022 forest fires affected 4.3 thousand hectares of forest. Considering the increase of fire risks due to the population flow into this region caused by full-scale russian invasion along with climate change scenarios (IPCC, 2022), existing approaches should be shifted to climate smart silviculture aiming to increase forest resilience. The key pillars of this approach should be ensuring of native hardwoods share in species composition, for appropriate sites or/and uneven-aged structure stands. Primarily, forest transformation and implementation of such approaches should be pursued on forest edges and in wildland urban interface zone base on silvicultural and close-to-nature forestry practices.

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Climate change affects the phenology of *Fagus sylvatica* in the Western Carpathians

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Studying the mechanisms underlying environmental control of tree phenology is crucial for predicting how trees will respond to climate change-induced conditions. This study aimed to investigate the effect of climate variables on the onset of phenological phases of European beech (*Fagus sylvatica* L.) in different forest vegetation zones (FVZ, Zlatník, 1976) of Western Carpathians. Analysed 78 phenological stations and 71 meteorological stations managed by Slovak Hydrometeorological Institute were classified into FVZ: 0 (Alluvial), 2 (Beech-oak), 3 (Oak-beech), 4 (Beech), 5 (Fir-beech), and 6 (Spruce-beech-fir). For each FVZ, the mean onset of phenological phases - leaf unfolding (BBCH11) and leaf colouring (BBCH94), and mean climate variables - precipitation (P), standardized precipitation index (SPI), climatic water balance (CWB), and maximum, minimum and mean air temperature (Tmax, Tmin and Tmean), were calculated.

Results of trend analyses point out that in the normal period 1991–2020, the mean onsets of BBCH11 advanced and BBCH94 delayed in all FVZ compared to normal 1961–1990. Partial correlations revealed that rising temperatures in months preceding the BBCH11 were the main driving factors of advanced BBCH11 across FVZ. Lower precipitation totals delayed BBCH11 only in FVZ 0. On the contrary, in FVZ 6, at higher altitudes with sufficient precipitation, the correlation with SPI indicated that an increase in precipitation above the standard conditions delayed the onset of BBCH11.

Rising temperatures and sufficient precipitation during summer are the assumptions for the later onset of BBCH94. However, correlations between P, SPI, and CWB in FVZ 2 and 3 and BBCH94 revealed significantly earlier onset when these variables were lower than usual. In the last normal period, we noticed decreased CWB, particularly during the growing seasons in FVZ from 1 to 4 which may considerably affect the production and resistance of beech forests in the Carpathians in the upcoming decades.

Keywords: *climate, drought, phenology, forest, trends*

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Vertical migration of alpine plant species on the Belianske kopa summit (Belianske Tatras Mts., Slovakia)

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Biodiversity on this planet is decreasing more and more, especially since the second half of the 20th century. The mountain ranges are important in terms of diversity, they have at least a third of the species from the entire species diversity of terrestrial plants. Especially, the alpine vegetation harbors a great diversity of species worldwide, including 8,000-10,000 species of higher plants. The alpine landscape represents a unique biogeographical unit of the Earth, which occupies 0.7% of Slovakia. Among the main processes of biodiversity loss in the high mountain landscape are the destruction, fragmentation and degradation of ecosystems, disruption of biogeochemical cycles, disposal of the environment, crossing the thresholds of ecological tolerance in the use of natural resources and the spread of invasive species. In recent decades, the biodiversity loss is mainly caused by human-accelerated climate change. Climate change will start irreversible changes in biodiversity (Steinbauer et al., 2018). Warmer climatic conditions lead to the rise of vertical migration of alpine plants. Alpine plant species migrate faster and faster (Steinbauer et al., 2018), they do not adapt and become extinct in a short time. In addition, they „displace“ native species at a specific altitude. In the submitted contribution, we study vertical migration of alpine plant species in the Belianske Tatras. In 2021, we modified the methodology of the Gloria network (Grabherr et al., 2000) and established a permanent monitoring on the Belianska kopa summit. At an altitude of 1835 m above sea level, we have not yet noticed significant changes.

Keywords: high mountain landscape, vertical migration, climate change, biodiversity, the Tatras

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Changes in the composition of araneocenoses in the Malá Lehota village (central Slovakia) in response to global climate and landscape changes over a long-term horizon

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The impact of recent changes in the agricultural landscape of Slovakia on araneocenoses is still insufficiently studied. For this reason, we realised the repeated study of the ground-living spider assemblages in the Malá Lehota village in Central Slovakia. In this research, we repeated the research spider assemblages from 2003 growing season at the same four study sites (meadows, grasslands) in 2019 using the same methodology (pitfall traps, same research period). The captured spider material was processed and evaluated with emphasis on the quantitative characteristics of the spider assemblages and their ecosozological significance. In total, we have recorded the occurrence of 117 spider species in the studied area (92 species – first research period, 81 species – second research period). The identified araneocenosis is dominated by wolf spiders (Lycosidae) with the most abundantly present species *Pardosa pullata* in both periods of research. We think that global climate and landscape changes that occurred between the two research periods (successional changes induced by reduced grazing, changes in temperature and moisture regimes, etc.) induced changes in the species composition of some of the dominant species of the study area (decrease in abundance of *Aulonia albimana*, increase in abundance of *Alopecosa trabalis*, *A. pulverulenta* and *Ozyptila simplex*). Of the six threatened and potentially threatened species listed in the Red List of Spiders (Araneae) of Slovakia (Gajdoš & Svatoň, 2001) identified in the first period of the research, only two ones were found in the second period of the research. In the second research period, the North American species *Mermessus trilobatus* was also detected in all study sites, demonstrating the penetration of alien species into araneocenoses. Our research has shown that changes in microclimatic conditions and also in agricultural landscape use can significantly affect the araneocenoses associated with this landscape type.

Keywords: *Agricultural landscape, Araneocenoses, Landscape changes, Spiders, Threatened species*

Acknowledgment: *This study was supported by the Slovak Scientific Grant Agency VEGA 2/0115/21.*

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Drought Patterns in the Western and Eastern Carpathians: a Focus on Montane Forested Regions

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Hydroclimatic extremes, particularly droughts, are main indicators of climate change in the Carpathian Mountains, with forests being particularly vulnerable to their impacts. This research aims to investigate the occurrence and distribution of droughts within the montane bioclimatic zone, which is predominantly covered with forests. The study employs the Standardized Precipitation-Evapotranspiration Index (SPEI) and Standardized Precipitation Index (SPI) based on weather station data from the Western and Eastern Carpathians between 1960 and 2021. Additionally, the indices from gridded databases (CARPATCLIM, European Drought Observatory) are utilized for comparison. The research findings demonstrate the influence of orographic transformations of regional circulation on local drought patterns in both the Western and Eastern Carpathians. The interplay between the North Atlantic Oscillation (NAO), Mediterranean Oscillation (MO), and Polar atmospheric circulations contributes to distinct spatial drought patterns throughout the year, particularly on the southeastern and northwestern macroslopes. Low-mountain regions with broad-leaf and mixed forests, particularly in closed inner valleys and along the border of the Western and Eastern Carpathians, experience the most extreme droughts in recent decades and heightened exposure to drought intensification. The highest probability for prolonged drought events is also characteristic of inner mountain valleys, as well as the northern foothills of the Western Carpathians and the southeastern macroslope of the Eastern Carpathians. The study also reveals a continental influence, as the low-mountain areas toward the east exhibit insignificant drying trends over time. The severity of droughts has increased the most during the spring and early summer months. However, in late summer and autumn, the frequency of droughts even decreased at higher elevations in the Tatra Mountains and Chornohora Mountains.

Keywords: *Carpathian forests, climate change, droughts, drought severity, drought intensity.*

Variability of cloudiness and sunshine in 2002–2022 in the Low Beskids, Outer Western Carpathians (on the example of the Research Station IGiPZ PAN in Szymbark near Gorlice)

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Cloudiness and sunshine are elements of climate that are determined, among other things, during ground-based meteorological observations. The degree of cloudiness of the sky and the type of clouds has a significant impact on the amount of solar energy that is delivered to the Earth's surface. Clouds, through their properties of reflecting, absorbing and scattering radiation from the sun and Earth, significantly affect the climate (Matuszko 2009).

The issues of variability of cloudiness, sunshine and their spatial distribution have been discussed either in general for the Polish territory or in detail, e.g. for Krakow, Lodz, Lublin (Warakomski W. 1961; Kuczmarski M. 1982; Wibig J. 2004; Adamczyk R., Ustrnul Z. 2006; Gluza A.F., Kaszewski B. M. 2000; Żmudzka E. 2007; Matuszko D. 2007, 2009; Szyga-Pluta K., Sypniewska L. 2018). There is less research on the Polish part of the Carpathians (Michalczewski J. 1955; Dubicka M., Limanówka D. 1994; Obrębska-Starkłowa B., et al. 1994). The aim of the study is to determine the seasonal variability of cloudiness and sunshine in the area of the Low Beskid Mountains, together with an analysis of the frequency of occurrence of a given cloud type. The data were collected at the Research Station of IGiPZ PAN in Szymbark near Gorlice; they cover the years 2002–2022 and come from three observation dates – 6, 12 and 18 UTC (until 2018). Among other things, average annual, monthly, seasonal (relative to thermal seasons) values of sunshine and cloudiness were calculated, and the frequency of occurrence of a given cloud type was analyzed. Following Żmudzka 2012, nephological characteristic days – cloudless, clear, cloudy and overcast – were determined.

Cloudiness and sunshine, as climate-shaping elements, fundamentally affect both biotic and abiotic elements of the natural environment (by affecting the distribution of air temperature and the spatial variation of precipitation and its frequency). Studying the trends of changes in these elements can contribute to the knowledge of climate change. The presented results can be applied in practice – to forest and agriculturally used ecosystems. The degree of cloudiness and the frequency of a given type of clouds affect the relative

humidity of the air and the degree of hydration of these types of catchments. In the social aspect, the presented research results can be applied in among other things and bioclimatology. The Carpathian Convention can also use the results in the aspect of land use development for example renewable energy sources.

Keywords: cloud cover, sunshine, cloud types, Low Beskid.

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LAND USE AND LAND COVER CHANGE 2

Historical and present changes in the landscape diversity and biodiversity in a selected part of the Lower Spiš (Slovakia)

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The character and intensity of industrial, agricultural, and social influences on the landscape and its elements, as well as subsequent trends in the landscape development and biodiversity of landscape elements, can all be assessed by looking at changes to the landscape and its structural elements. Because any alteration to the natural environment results in a change in the landscape, human activity in the area alters the landscape's structure and appearance. The way that land is used, the development of new components, and the usage of agricultural and forest soils all contribute to the existing landscape's characteristics and have a substantial impact on biodiversity. The landscape structures that control the horizontal and vertical arrangement of the landscape elements, their combinations, qualities, and relations are thus a useful predictor of the current status of land usage. The area can no longer be farmed due to the overgrowth of pastures and meadows with non-forest tree and shrub species at various stages of succession. Based on the present landscape structure (2020–2022), the CORINE land cover databases (1990 and 2018), and the DATAcube databases of the Statistical Office of the Slovak Republic (1996–2022), we assessed the usage of agricultural landscapes. The development of land resources through changes in the structure of the agricultural landscape were assessed as changes in its usage. The representation of the two primary categories, agricultural soil and non-agricultural soil, was evaluated in light of these changes.

Keywords: *land use, changes in landscape structure, statistics, agriculture, biodiversity*

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Land-Use Changes of the World Heritage Site of Vlkolínec (Slovakia) Since the Late Eighteenth Century

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The study focuses on the United Nations Educational, Scientific and Cultural Organization (UNESCO) World Heritage Site of Vlkolínec (Slovakia), changes in its cultural landscape and the possibilities of its preservation for future generations. However, it is also a living settlement with residents who have demands for their standard of living. To analyse the development of changes in the landscape of the Vlkolínec protection zone, we used available relevant data such as historical maps and aerial photographs from selected time horizons 1769, 1823, 1949 and 2022. Overall, we interpreted a total of 13 landscape elements, paying special attention to historical landscape structures. For the land use elements, we focused mainly on determining their area and percentage of the landscape in relation to their changes in the period under review in the context of natural and socio-economic conditions. The aim of the study is to analyse the potential and the development of the UNESCO site in Vlkolínec according to maps, different forms of literature and other information sources, to present the changes in the structure of cultural landscape in the area based on available older photographs, historical maps and aerial photographs. It aims to identify landscape structures and propose a strategy for sustainable tourism development at the Vlkolínec that preserves its cultural, natural and landscape values.

Keywords: *Vlkolínec, UNESCO, Slovakia, historical structures, land use changes.*

Acknowledgment: *This study was supported by Scientific Grant Agency VEGA, project No 02/0077/21 Integration of supply of selected ecosystem services for societal demand in terms of developing sustainable forms of tourism.*

Analysis of the diversity of cadastral communes in Galicia located in the Carpathian region in the mid-19th century

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Skorowidz wszystkich miejscowości położonych w Królestwie Galicyi i Lodomeryi wraz z Wielkiem Księstwem Krakowskiem from 1868 presents various types of data for approximately 6000 cadastral communes located in Galicia, including those in the Carpathian region. It refers to topics such as administrative classification, religious affiliation, population and data concerning four types of land use: arable land, pastures, meadows and gardens, as well as forests, which were divided into two types of ownership: great landed property and peasant-owned. This data was derived from the population census conducted in 1857 and from the so-called Galician cadastre, which was prepared between 1844 and 1854. For great landed property, the owner was also indicated and they were classified into one of four ownership categories: private, state, communal, or religious.

The aim of the research, which will be presented in the form of a poster, is to present and analyze various types of administrative, religious, demographic, ownership-related, and land use-related relationships for the cadastral communes of Galicia located in the Carpathian region. The aforementioned data allows for the reconstruction of the land use structure for individual communes, identification of dominant types of land use or forms of ownership, differentiation of surface areas, as well as other factors such as religious affiliation or the presence of parishes in specific communes.

Stability and pool of Soil Organic Matter under different types of land cover and under the influence of various soil-forming processes on the example of the Gorce Mountains (S Poland)

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One of the main strategies for mitigating climate change is the sequestration of carbon in the form of above- and belowground organic matter. In this case, mountainous areas may be particularly important, because due to the relatively harsh climatic conditions limiting the processes of microbial decomposition, they have a high potential for storing organic compounds in a form of soil organic matter (SOM). On the other hand, mountains may be particularly vulnerable to the effects of global change, i.e. global warming and land cover change, that may alter soil organic matter pools and their stability. The Gorce Mountains in southern Poland is a good example of an area where land abandonment and the effects of global warming have caused significant changes in the land cover. In addition, the soil cover of this region typical of mountain areas is characterized by a distinct local differentiation of soil-forming processes. Thus, the aim of this study was to determine the impact of different land cover together with various soil-forming processes on SOM pool and its stability.

Soils located under various types of land cover (ancient forests, successional forests, shrubs, meadows covered with shrub vegetation and grasslands) and characterized by different soil-forming processes (Podzols and Cambisols) were tested in terms of the SOM pool and its stability. Soils under ancient forests and under meadows with shrub vegetation were characterized by the largest SOM pool in the first 30 cm of depth and the lowest under successional forests. However, the stability of SOM was more subordinated to the soil-forming process than the type of land cover. In the surface horizons of both Podzols and Cambisols, most of the SOM was stored in the form of particulate organic matter which is a relatively unstable SOM fraction. On the other hand, the subsoil horizons in Cabisols were characterized by a significantly higher share of resistant mineral-associated organic matter than in Podzols.

Keywords: *LUCL change, Land abandonment, climate change, soils, C sequestration*

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Effects of land-use changes on the connectivity of brown bear (*Ursus arctos*) habitats in the Low Beskid Mts region

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In recent decades, improvements in the conservation status and habitat connectivity of large mammals in Europe have supported their recovery to areas they occupied decades or even ages ago (Chapron et al., 2014). However, knowledge of how this process has evolved over time is largely lacking due to a lack of detailed land use data from the past. In this study, we use a series of historical land use reconstructions to assess the impact of land-use changes on brown bear (*Ursus arctos*) habitat connectivity in the Low Beskid Mts, Polish Carpathians, since the mid-19th century. We created a set of resistance surfaces for four time periods: 1860s, 1930s, 1970s and 2013, reflecting the local costs of brown bear movement between the habitats located in the eastern part of the Polish Carpathians, where large-scale, post-war depopulation occurred. For each period, least-cost paths and potential migration corridors were identified. Among the variables we used to construct the resistance surfaces, we used, e.g. forest cover persistence, distance to settlements, or distance to the transportation network for each of the specified period. The results of the analyses showed that a rapid increase in forest cover combined with a decrease in settlements led to a significant improvement in habitat connectivity. This was mainly reflected in an increase in the number of identified least-cost paths and corridors, but also in the proportion of forested areas within the corridors. The results confirm the overall positive impact of the observed land use changes on habitat connectivity for large mammals, which may support their recovery in the new areas in the future.

Keywords: land use change, habitat connectivity, brown bear, depopulation, the Polish Carpathians

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Verification of the taxonomic position of soils affected by a 50-year history of Land Use and Land Cover changes on the example of the Jaszcze and Jamne Valleys in the Gorce Mountains (S Poland)

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Due to the significant progress in soil science that has taken place in recent decades, some information contained in soil maps requires verification and updating. In addition, some changes in land use and land cover (LULC) as a result of global change can affect soils to such an extent that they alter their pedogenic pathway. The aim of the study was to compare the systematic position of soils in a mid-mountain area affected by LULC change. In the 1960s, the Jaszcze and Jamne Valleys were the subject of extensive geographical research, including studies on the diversity of the soil cover, the results of which were presented on a large-scale map of Adamczyk and Komornicki (1970). a helpful tool in soil verification are the latest editions of the Polish Soil Classification (Kabała et al., 2019) and World Reference Base for Soil Resources (IUSS Working Group WRB, 2022). During the fieldwork carried out in July 2022, approximately 30 soil profiles were described and assigned to the different taxonomic units. The tested soils were: Dystric and Eutric Cambisols, Podzols, Histosols and Luvisols. The properties of analyzed soils (e.g. soil organic matter content, soil pH) were changed slightly due to LULC change, whereas the systematic position of soils in most of the analyzed cases remains consistent with the earlier findings. Due to differences in the recognition of some soil-forming processes now and in the past, there were few discrepancies, e.g. in distinguishing clay-illuvial soils (Luvisols).

Keywords: *LULC change, Land abandonment, soil properties, soil classification*

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CONSERVATION AND SUSTAINABLE USE OF BIODIVERSITY 2

Linking management, plants, soil invertebrates and environmental variables in pastures from S-W Făgăraș Massif (Romanian Carpathians)

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The Făgăraș Massif dominates the Romanian Carpathians in extent (2300 km²) and height (M.P., 2016). It is oriented east to west, with very diverse habitats and grassland types, located on slopes with southern and northern aspects. Used for sheep grazing for centuries, the grasslands have experienced different anthropogenic impacts depending upon local grazing custom (with milk-producing sheep vs. barren sheep).

In their use as pastures for sheep grazing, the natural and anthropogenic grasslands of the alpine and subalpine zones of the South-West Făgăraș Massif were of very poor to medium quality (Nicoară et al., 2020; Onete et al., 2020; 2021).

Our study focused on two pastures with different intensities of grazing impact, where, at different altitudes we established ten transects, each comprising ten quadrats. In each quadrat we recorded: 1) each plant species and its percentage cover; 2) environmental factors (temperature, humidity) for air and soil and soil penetrability; and, using soil samples collected at every quadrat, we 3) made an extraction for invertebrates; and 4) made a chemical analysis of the soil in the laboratory (pH; electric conductivity; humus, nitrogen, phosphorus, potassium, C/N, organic carbon). These data were assembled in a database for statistical analysis.

The analysis of the database showed that the dominant vegetation belongs to the Association *Viola declinatae*-*Nardetum* Simon 1966. Plant species diversity is positively correlated with invertebrate diversity and modifies local environmental conditions (light incidence, temperature, soil moisture and substrate chemical quality that becomes later incorporated as detritus) (Carrillo et al., 2011; Chiriac et al., 2020).

Physical and chemical factors determine the variability in time and space of the structural and functional parameters of plant species and implicitly of invertebrate populations and therefore their ecological role in the functioning of ecosystems.

Keywords: Romanian Carpathians, management, plants, soil invertebrates, environmental variables

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Participatory approach and regional stakeholders' platforms to improve wolf-human coexistence in the Alps. Hints from the LIFE Wolf Alps EU project

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The wolf presence goes far beyond the ecology issue and involves economic, political and social aspects. Its influence on community life is greater the more the space of action of humans and wolves is shared. Technicians and researchers agree that stakeholder's engagement in conservation programs is an essential requirement to ensure the achievement of the set goals, and to set up solid and participatory coexistence paths. It is important to reach out the actors who interact in different ways with the wolf: breeders, hunters, politicians, journalists, hikers, tour operators and educators, etc. The Project LIFE WolfAlps.EU team used a set of participatory approaches to periodically involve local main stakeholders of each of the project pilot sites across the Alps (farmers, hunters, environmental protection associations).

Authors will present the main results of two specific engagement actions, the thematic platforms and the local meetings, to highlight critical issues and needs, identify and facilitate solutions, and share relevant project results with each stakeholder.

During the project, all partners oversaw organizing dialogue platforms with stakeholders. These participatory meetings function as "antennas" to detect consensus on the project's actions, and to understand the main issues on which intensify efforts. The platforms were also an opportunity to disseminate project vision, mission, and results. All partners also had periodically organized different local thematic platforms for discussion according to the local context, urgent issues and needs of the participants.

The results, which will be presented in detail, demonstrate the critical issues related to coexistence projects with large carnivores, but also the many opportunities brought into play by almost all the stakeholders involved.

Keywords: *Wolf-human coexistence, Alps, human dimension, stakeholder engagement*

Using modelling of biodiversity in the protected landscape areas Beskydy and Kysuce in the Czech and the Slovak Republics

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The aim of the study is to model the status of threats to the biodiversity of forest habitats using the GLOBIO3 model and to select valuable natural habitats using the Marxan model for the Beskydy (CZ) and the Kysuce (SK) protected landscape areas in the Czech and the Slovak Republics. GLOBIO3 is a conceptual model developed to assess biodiversity in the past, present, and future (Alkemade et al. 2009). The main data sources for the applied GLOBIO3 and Marxan models were the Habitat Mapping Layer for natural habitats in the Czech Republic and the Corine Land Cover layer for unnatural habitats. The GLOBIO3 model was converted (transformed) to CZ-GLOBIO by adjusting global to local scales and using habitat quality and naturalness data instead of species occurrence data (Pechanec et al. 2021). Five main factors affecting biodiversity were used: land use change (MSALU), infrastructure development (MSAI), landscape fragmentation impact (MSAF), atmospheric nitrogen deposition (MSAN), and climate change (MSAcc).

The Marxan model was developed by Ball et al. (2009) to plan new representative and spatially compact protected areas for landscape planning. The model selects a set of planning units (PUs) containing all defined conservation features (CFs) while minimising the total cost of the selected PUs. Natural habitats were selected by the Marxan model according to three scenarios to protect 25%, 50%, and 75% of their total area in the Beskydy and the Kysuce protected landscape areas. In addition, we compared two versions of habitat mapping corresponding to 2006 and 2016 in the Czech Republic. Based on the applied models results and comparison of data between 2006 and 2016, the threat and loss of natural forest habitats were identified. To preserve natural forest habitats suitable management is needed, such as reducing habitat fragmentation, leaving dead wood on site or supporting natural regeneration.

Keywords: biodiversity, forest habitat, natural habitats, modelling, protected area

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Using species distribution models as a tool to predict occurrence of *Fallopia* taxa in Slovakia.

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Invasive species are now considered the second biggest threat for biodiversity and have adverse environmental, economic and social impacts. They are recorded as the sole driver of extinction in about 20% of species extinctions and are a significant concern for mainland species currently threatened with extinction (Bellard, 2016). Species distribution models (SDMs) are considered as a cost-effective and sound tool for biodiversity conservation and sustainable management. In our work, we designed models of species distribution for invasive species of *Fallopia*. We used the presence and absence data of three species - *Fallopia japonica* - Japanese knotweed, *Fallopia sachalinensis* - Sakhalin knotweed and their hybrid *Fallopia x bohemica* - Czech knotweed. 12 species distribution models were designed and their accuracy was evaluated. The final simplified logistic regression model showed the three most important prediction variables lead by distances from roads and rails, then type of soil and distances from water bodies.

Keywords: Species distribution models, invasive species, biodiversity loss, *Fallopia* taxa

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EDUCATION FOR SUSTAINABLE DEVELOPMENT

The Green Week – a step forward in education for sustainable development in Romania

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In the 2022- 2023 school year Romania initiated a compulsory program for pre-university education named The Green Week. This program has the goal of implementing the national Strategy on the education for the environment and climate change 2023-2030 and contributes to – alongside with other institutional tools- student' knowledge, teachers' skills and attracting resources to support education.

A matrix analysis, applied to 102 projects presented on the websites of secondary schools and high schools which totaled 1836 implemented activities, reveals: a lower percentage (37%) of overlap with the goals of the national program; inefficient use of the local learning resources (only 17%); poorly presented contents which bolster student' ability to investigate the reality surrounding them. Through the method of superimposing the activities implemented with the goal of the national project and of ODD4 it results in a lower value (18,68%), so the potential growth of this project is high.

The causes of these results are the hasty preparation of the program, without a preliminary training of teachers and without providing them the necessary learning resources and tools, but also a poor representation in the analysis of schools in the Carpathian space (only 6 out of 102 and those from small cities, not from rural areas) under the conditions in which the information was collected from the schools' websites.

The positive outcomes/elements of the implementation of the program consisted in the visible support of the civil society and of public or private institutions with the skills and resources relevant to the subject of the project, furthermore the representation in the press generated a debate in Romanian society on topics such as: climate change, the investigation and evaluation of environmental problems and sustainable development.

Keywords: *The Green Week, strategy, sustainable development, climate change, environment*

Students on sustainability – first results of a V4 research initiative

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In order to strengthen the international cooperation among environmental educators of the Visegrad countries, a representative sample survey was conducted within the framework of the Teachers and Students about Sustainability Research Programme in October 2022 among 11th grade secondary school students in Hungary, Slovakia and Czech Republic. The main aim of the research was to reveal students' views on sustainability issues. This report summarizes the basic psychometric characteristics of the scales used in the research.

The total sample consists of 6477 respondents, 3434 from Hungary, 1656 from the Czech Republic and 1387 from Slovakia. In the joint (Hungarian, Czech and Slovakian) sample there are more boys (52%, N=3365) than girls (48%, N=3112). a similar gender rate was found in each national sample.

In Hungary and the Czech Republic, a two-stage random sampling procedure was used to first select schools using PPS (Probability Proportional to Size) procedure and then to randomly select a class within the sampled schools to fill in the questionnaire. In Slovakia, the data for the sampling were not available, so the questionnaire links were sent to all institutions via the regional education authorities. The participating class within each school was also randomly selected. The deviation of the samples from the distribution of the population was corrected by multivariate weighting (criteria: region, school type, school owner).

The joint survey contained 118 items (plus additional country-specific questions at the end of the questionnaire). The most relevant scales were on students' attitudes toward environment (Manoli et al. 2007; Schultz, 2001) and climate change (Christensen and Knez 2015), on pro-environmental behaviour (Kerret et al. 2020), action competences (Olsson et al. 2020), eco-anxiety and eco-guilt (Ágoston et al. 2022). The questionnaire also contained questions on students' demographic and socioeconomic background.

Keywords: *education for sustainable development, environmental attitudes, climate change*

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The role of universities in the formation of global principles of sustainable development

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Achieving Sustainable Development Goals (SDG-30) in the Carpathian Region requires profound socio-economic transformations in Ukrainian society and new approaches to building human resources. This direction actively implements a volunteer project International Carpathian School located in the Ukrainian part of Carpathians in both Ivano-Frankivsk and Chernivtsi oblasts. Conceptually, civic education activities have a well-established practice of developing within the framework of the "third" mission of universities. In spite of the Triple Helix model where technologies are centred, Ukraine is testing their own model based on civic education which is socially oriented, and known as a "bottoms up" strategy. Contrasting to environmentally sound biological, this model is based on geography approaches, which have more suitable natural and social dimensions. It is more socially oriented on values and attitudes and transferring multidisciplinary knowledge in both formal and non-formal and vocational (inclusive) education. It aimed at developing the skills and competencies of civic activists, students and other interested social groups.

The Schools' educational activities were structured in cooperation with universities of the Baltic Sea Region and based on the Quadruple Helix model. It was tailored to the local environment allowing Ukrainian students to be acquainted with the best practice in waste management and open a door to the European labour market. Simultaneously, the School provided a prospect for local scientists in maintaining professional links with their foreign colleagues. Having a central geographical position in CEE, the Carpathian School may have a good chance to become a placement for promoting students' mobility and employability to Visegrad countries and Carpathian Region that is especially important for Ukrainian educational institutions involved in training specialists for post-war infrastructure reconstruction and integration into European space.

Keywords: Carpathian Region; Education; Transboundary Cooperation; Sustainable Development

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Social and environmental education in the Tatra Biosphere Reserve as a task for the implementation of Agenda 2030 (Slovakia)

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In biosphere reserves (BRs), especially for the period 2020-2030, it is important to strengthen education for sustainable development (ESD). Guidance for achieving progress in implementing the Sustainable Development Goals (SDGs) is provided by UNESCO's global framework itself. Article 13 of the Carpathian Convention, which outlines provisions on public information, education and participation (Mitrofanenko et al., 2020), is particularly important. Several academic and political documents also emphasize the role of education in the implementation of the 2030 Agenda (UNESCO, 2019). In strengthening ESD in BRs, the general framework of social learning is also presented in SDG 4.7 (UN, 2015). Educational approaches are needed that facilitate society's transition to sustainable living (UNESCO, 2014). For the Tatra BR, this social and environmental learning represents mainly the inclusion of formal, informal and non-formal education, strengthened by the academic and scientific community. In this study, we are looking for answers to the questions: How do schools/teachers in the Tatra BR use the territory of the biosphere reserve? How they learn to be able to perform quality ESD? What obstacles do they overcome and how? How can academic research institutes cooperate with the Tatra BR in its activities environmental education for teachers and pupils? How can the scientific community in general contribute to identifying a strengthening the ties between formal, informal and non-formal

education? Could universities or stakeholders play a role in supporting teachers? The study presents the current state of social and environmental education in the Tatra BR.

Keywords: *Tatra Biosphere Reserve, biosphere reserve, education, learning for sustainability, Agenda 2030*

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Ancestral education for a change in the sustainable development of the community in Santiago of Chile

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The objective of this work is to show those educational experiences based on participatory methodologies, which address sustainability as a cornerstone for human development in the school and university educational environment. As well as generating another form of education based on respect, ancestral, rural, indigenous wisdom, with traces that not only speak from a Western urban knowledge, but also from rurality, and that knowledge that have been forgotten over time. From this point of view, it is important to emphasize that the Mapuche vision in Chile becomes relevant thanks to the new intercultural policies, and with this, the low education in the ancestral worldview that we have as a country has become visible.

The justification and importance of the theme of this work lies largely in the western, capitalist and bureaucratic way in which education has been understood during the last centuries. Leaving behind those educational forms from rurality, with knowledge of the land, a knowledge based on the field and its animals, as well as the ancient mechanisms of sustainability and support for the regeneration of species. In this sense, it is important to understand that education must be open, not only to new ways of understanding and participatory methodologies, but also to look back at those ancient wisdoms.

The methodology of this work has been the collection of information at the university level, and how the structure has been molded in conjunction with the new needs, as well as the intervention as a result of challenges; the growing challenges related to new knowledge that is beginning to take on greater relevance in our current culture.

It is proposed to address those related issues such as new ways of understanding education, eliminating the commercial concept of Western education, as well as eliminating the concept of success, and formal education as a mechanism to achieve a happy life. Understand education in a broad spectrum and provide new ways of educating the population. The presentation will aim to draw potential links with experience of education in the Carpathian region.

Keywords: *Education, Ancestry, Participatory Methodologies, Development*

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FORESTS, THEIR MANAGEMENT AND GOVERNANCE

Comparing natural and human disturbance parameters as a reference for sustainable forest management in the Carpathians and for Europe

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In Europe as for the Carpathians, there has long been interest in natural dynamics silviculture (NDS) to provide a full spectrum of seral habitats and

structural conditions required by forest biodiversity, including species that are poorly represented in intensively managed forests. However, adoption of NDS has been limited by incomplete understanding of the ranges of variability in disturbance regimes, including frequencies, spatial attributes, and severities. Addressing this constraint in European forest management, we adapted a “comparability index” (CI) that was first developed in the US to compare natural disturbances and forest management effects. We extended the original concept that included spatial and temporal axes by adding disturbance severity (i.e. tree survivorship or retention) as a third dimension. We populated the model by compiling published data on disturbance dynamics for four major forest types (i.e. spruce, beech, oak, and pine-dominated). Data on silvicultural systems by country and forest type were obtained through an expert-based process employing standardized estimation protocol. The data for both natural and harvest disturbances were visualized in three-dimensional plots indicating ranges for frequency, size, and severity. We developed an algorithm to calculate the index values for bivariate comparisons. The results indicated that natural disturbances are highly variable in size, frequency, and residual structure, but European forest management fails to encompass this complexity. The CI showed the highest congruence between uneven-aged silvicultural systems and key natural disturbance attributes. Even so, uneven-aged practices emulate only a portion of the complexity associated with natural disturbance effects. The remaining silvicultural systems perform poorly in terms of retention, especially, as compared to tree survivorship after natural disturbances. Our results and the CI will help Carpathian forest managers to expand their portfolio of silvicultural systems to sustain and conserve forest biodiversity, while providing a broad array of ecosystem services (Aszalos et al. 2022).

Keywords: *close-to-nature forestry, deadwood, emulation of natural dynamics, sustainable forest management, natural disturbances, natural dynamics silviculture*

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Near to real time forest monitoring and forest cover loss assessment in Ukraine

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Disturbances caused by storms, bark beetles, and fires have increased in Ukrainian forests throughout the twentieth century and are likely to increase further, resulting in a wide range of negative impacts on the quality of life, the economy, and the environment. As a result, there is an urgent need to provide up-to-date and harmonized information on forest health and vitality, including forest disturbances (i.e., forest fires, storm damage, drought stress, insect and disease outbreaks), which must be readily available to end-users, i.e., forest policy, forest administration, and forest management planning entities.

The Vegetation indexes, like the Normalized Difference Vegetation Index (NDVI), are a robust tool for identifying changes in forest characteristics. Within the DIABOLO project, the NDVI-based approach was implemented to give information on disturbance indications in near real-time and to give reliable information on significant forest disturbances in the form of annual maps. The approach was tested in Ukrainian Carpathians where clear-cuts are a standard forest management activity and the entire automatic approach. The results of near real-time implementation achieve higher producer accuracies (hotspots where disturbances may have occurred) and the results of the annual mapping approach achieved higher user accuracies (areas of reliable significant disturbances which could be directly targeted using management intervention). The methodology can produce even higher quality results with improved forest masks and improved cloud and cloud shadow masks than were available during this study.

Also, during the war, we continued to monitor particularly valuable forests in the Ukrainian Carpathians and territories affected by the war. For this purpose, a method of determining areas of forest cover loss based on Planet Scope satellite images and their assessment based on forest management materials was developed and applied.

Keywords: forest disturbances, clear cutting, forest management, forest cover losses

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Exploring the dynamics of trees spring phenology in the Polish Carpathians using Sentinel-2 time series

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Phenology serves as a critical indicator of ecosystem responses to climate change, and remote sensing techniques offer valuable tools for studying phenological patterns over large areas. This study explores the complex relationship between changing environmental conditions and the spring phenological dynamics in the Polish Carpathians, known for their high ecological value and diversified environmental conditions. Our study aims to quantify and understand the impact of different environmental drivers on spring phenological events in this region.

We utilized Sentinel-2 imagery from 2018 to 2023 and calculated two spectral indices: Meris Terrestrial Chlorophyll Index (MTCI) and Enhanced Vegetation Index (EVI). Then, the time series were modeled using Generalized Additive Models, and the Start of the Season (SOS) phenological metric was calculated. Different tree species including common beech, silver birch, European larch, and common hornbeam, were analyzed separately.

We investigated various factors which may have an impact on SOS, including topography, longitude, latitude, and meteorological conditions. We specifically assessed the effect of air temperature conditions on the onset of spring activity for different species. To assess general spring temperature conditions, growing degree days (GDD) for 0°C and 5°C base temperatures were employed across six individual seasons. The study also focused on extreme temperature events, such as warm and cold spells, which effects were evaluated based on their intensity and timing within the season.

The results show that the elevation impact on phenology timing is the most important, however, this relationship is not linear. Differences in SOS along elevation gradients are approx. 3-4 days/100 meters for common beech stands, and the impact of spring temperatures on SOS is evident. Moreover, the stands situated at the highest elevations exhibit the largest inter-annual variations in phenology.

Keywords: *forest, trees, phenology, remote sensing, Sentinel-2, air temperature*

Management, not climate change, is the main factor of the future Carpathian forest landscape

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We used Landis-II model (<http://www.landis-ii.org>) to simulate future evolution of managed forests in the Tysa headwater basin, Ukraine (100 150 ha), where all the main central-European natural forest types (oak, beech, hornbeam, sycamore, fir, and spruce) are present alongside extensive areas of spruce plantations. We applied five scenarios of climate change (baseline and RCPs) and disturbance regimes (wind and spruce bark beetle) as well as three management scenarios: business-as-usual (BAU), current adaptive (CA), and foresighted adaptive (FA). The adaptive scenarios, in comparison with BAU, provide for the increase of harvesting area from 7% to 10% per 10 years and replacement of natural regeneration by planting adaptive species (oak, beech, fir – instead of spruce) according to current (CA) and future (FA) site conditions. The simulation period was set for 250 years, while the management was applied during the first 100 years only.

The simulations revealed that climate change will have marginal impacts on harvested volume – up to 0.8% STD within the five climate scenarios. However, CA and FA management, in comparison with BAU, will on average increase harvested volume by 34-36% during the 21st century, and will be sustainable for all the main species, except spruce. Also, management will have a decisive impact on the aboveground live carbon (ALC) far beyond this century. BAU management is sustainable for all species including spruce, and will afford ALC increase by 6-8% till the end of the century, but will cause, depending on the climate change scenario, very diverse ALC trajectories in the 22nd century leading to changes from +20% (RCP2.6) to -17% (RCP8.5). CA and FA management will cause, depending on the severity of climate change, increase (+6%) or decrease (-3%) of ALC till the end of the 21st century, but will result in the significant increase of ALC during the 22nd century – from 23% (RCP8.5) to 38% (RCP2.6).

Keywords: Carpathian Mountains, forest landscape, LANDIS-II, climate change, forest management

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Tree aboveground biomass increment and mortality in the Gorce National Park

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Within the present study, we aimed to isolate drivers of tree biomass increment, mortality, and recruitment in the Gorce National Park (GNP), Outer Western Carpathians, Poland. We used a unique database consisting of information collected between 1992 and 2017 within 389 permanent monitoring plots. This allowed us to calculate tree biomass and its increments and model them using a set of explanatory variables: proportion of particular tree species, mean temperature of the coldest quarter, mean precipitation of the warmest quarter, elevation, topographic wetness index, stand basal area, diameter heterogeneity expressed by the coefficient of variation, and conservation regime. We applied generalized linear mixed-effects models.

In a large part of the GNP area, tree biomass increased. In the central and southern parts of the park, tree mortality was higher than in other parts, especially between 2002 and 2007, due to bark beetle outbreaks and intense wind damage. Stand dynamics of all species depended mainly on species proportion in stand biomass. Recruitment decreased with basal area and slope but increased with potential soil water content and tree diameter heterogeneity. *Picea abies* increment increased with elevation but decreased with basal area, slope, and tree diameter heterogeneity and weakly increased with mean temperature of the coldest quarter. Water retention at the plot level decreased mortality and increased recruitment of the studied species. In addition, the increment was lower in strictly protected forests, while mortality was higher. Our study provided quantitative evidence of how climate, geomorphology, and forest stand characteristics modify stand dynamics.

Keywords: tree biomass, modelling, monitoring, climate changes, geomorphology

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Towards Close-to-Nature Forestry: Tracking Forest Changes to Improve Management Using Photospheres with the Sylvotheque.ch Platform

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This paper discusses the utilization of photospheres as a valuable tool for foresters to effectively monitor and track forest changes, thereby enhancing management practices towards close-to-nature approaches. Photospheres are spherical panoramic images that provide a comprehensive 360-degree view of the forest, capturing details from the ground to the treetops. This technology enables researchers and forest management professionals to visually track changes over time to better understand natural processes and the effects of silvicultural interventions. We will present the martelage.sylvotheque.ch (MSC) internet platform, developed by BFH-HAFL (School of Agricultural, Forestry, and Food Sciences at Bern University of Applied Sciences), which utilizes photospheres to document and share about forest dynamics in manifold situations. Since its inception in 2014, the MSC platform has amassed a substantial collection of forest images and continues to expand its presence, including in Ukraine. Moreover, this paper highlights how photospheres could be applied to support post-war recovery efforts in the forestry sector and promote close-to-nature silviculture and sustainable forest management by forest professionals and policy makers. We will address the challenges and opportunities of employing photospheres through the martelage.sylvotheque.ch platform in Ukraine and discuss potential future application for fostering post war forest recovery in Ukraine.

Keywords: *Close-to-Nature Forestry, digitalisation, decision-support system, sustainable forest management, innovations*

Acknowledgement: *Martelage.sylvotheque.ch is supported by the Federal Office for the Environment (FOEN), the Canton of Geneva, and Bern University of Applied Sciences (BFH). We would like to express our gratitude to Ulrich Fiedler and Hugues Michel from the BFH School of Engineering and Computer Science for their support in the IT component of this project. The cooperation with our Ukrainian partners is supported by the School of Agricultural, Forestry and Food Sciences (BFH-HAFL) and was initiated to assist Ukrainian forestry in strengthening its capacity for post-war recovery. This collaboration was launched in February 2023 during the BFH Mobility Program for Ukrainian researchers, who are continuing their research activities while residing in Ukraine during the war.*

Seasonal trend analysis of MODIS vegetation index time series for the fir and beech forest stands in Carpathians

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European forests are facing enormous threats from rapid global climate change. In predicting the effect of climate change on future performance of tree species, a geographical, namely latitudinal gradient may serve a useful space-for-time substitution (Čater & Levanič, 2019).

This study focuses on analysing the seasonal and inter-annual change trends for European beech (*Fagus sylvatica* L.) and silver fir (*Abies alba* Mill.) sites in the Carpathians, specifically examining eight sites along a geographical gradient. Time series data from the MODIS Terra and Aqua satellites, spanning from 2000 to 2022, were utilized to expand and update our understanding of the extent and change trends of these forest stands. MODIS data with meteorological parameters (temperature, precipitation and evapotranspiration index) were used to compare annual forest development at study sites and to extract phenology-based metrics (e.g., start and end of the growing season, length of the season, day of phenology maximum).

The analysis included two vegetation indices - the Normalized Difference Vegetation Index (NDVI) and the Enhanced Vegetation Index (EVI), taking advantage of their distinct spectral properties. Phenology extraction was performed using the TIMESAT and DTimeS software packages and the phenex R package, while the bfast R package was used to estimate the time and number of abrupt changes within the time series. Preliminary results demonstrate varied responses of the study forest sites to climate change during the analysed 22-year period.

Keywords: climate change, satellite remote sensing, phenology, time series, fir, beech

Acknowledgment: This research was supported by the Czech Science Foundation and Slovenian Research Agency, grant number GA ČR ARRS 21-47163L.

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Floristic composition, diversity and similarity analysis of forest ecosystems in Romanian LTER-sites

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International Long-Term Ecological Research (ILTER) and LTER-Europe were designed for interdisciplinary research and monitoring of ecosystems on large-scale. In Romanian LTER-sites, transdisciplinary studies are conducted on the monitoring of air pollution, bulk precipitation, throughfall, soil conditions, nutritional status, health and growth of key tree species. Also, floristic structure of the selected stands and biodiversity assessment are an important part of these studies. The Romanian LTER monitoring network consists of: Bucegi-Piatra Craiului LTER-site (22 permanent plots – PP); Retezat LTER-site (11 PP); and Lunca Mureşului LTER-site (2 PP). All sites are located in natural and national parks, in the South-Eastern Carpathians (in Bucegi Natural Park, Piatra Craiului and Retezat National Parks) and in the Mureş river floodplain, respectively in Lunca Mureşului Natural Park.

The vegetation surveys were based on the Braun-Blanquet method, combined with numerical syntaxonomic approaches (Hierarchical clustering and Non-metric Multidimensional Scaling).

Within all plots, 296 vascular plant species and bryophytes were found. The average number of species per plot is 25.43 for the sites in the South-Eastern Carpathians, while for the site located in the Mureş river plain is 16.10. The highest values of α -diversity (species richness and Shannon-diversity index) were recorded in a mountain mixt forest community with spruce (Ass. *Leucanthemo waldsteinii*-*Piceetum* Krajina 1933) located in Bucegi Natural Park, due to the presence of several microhabitats (spring, stream, rocks). Using the numerical syntaxonomic methods, the identified eight forest communities fit into three main clusters, based on their floristic similarity and on the ecological indicator value of the species, especially in the herb layer.

Our results support the importance of indicator species and the use of α -diversity in biodiversity assessment of Carpathian forests.

Keywords: South-Eastern Carpathians, protected areas, herb layer, α -diversity, indicator species

Soil development and properties under trees

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Rock weathering drives landform formation and soil evolution. The main focus of the present study is the biological component of weathering caused by tree root systems and soil properties under trees. Our goal was to assess the impact of tree roots and associated microbiota on the potential level of biological weathering. Soil samples were taken from tree root zones of Norway spruces from predefined sampling positions. Soil samples were the subject of laboratory analyses, including the content of Fe and Al (amorphous and labile forms), C, N, and soil pH. The microbial functional diversity of soil microorganisms was determined using the Biolog (EcoPlate) system. Rock fragments were collected for mineralogical and a subject of optical microscopy and cathodoluminescence analyses in order to examine their mineralogical composition.

By following the existing net of bedrock discontinuities and hillslope microrelief, tree roots developed a great variety of root system patterns. When entering rock fractures, they change the intensity of biomechanical weathering and soil properties. However, the highest biological activity expressed by the degree of utilization by microorganisms of 31 different carbon sources was found in the control samples.

Tree roots changed the pattern of soil formation and explained the existing pattern of soil chemical properties, microbial activity, and potentially biological weathering intensity. It can be concluded that trees and their root activity cause bedrock retreat and soil production in the long-term perspective.

Keywords: *biological weathering, soils, microbial biodiversity, Sudety, Carpathians*

Acknowledgment: *The study has been supported by the Polish National Science Centre (project no: NCN2019/33/B/ST10/01009).*

HUMAN-WILDLIFE COEXISTENCE

Natural and anthropogenic drivers of brown bear damage occurrence

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The conflicts arising from wildlife damage to human property are a main challenge for biodiversity conservation worldwide. Wildlife damages can lead to significant economic and emotional losses, fueling opposition towards wildlife conservation and even triggering behaviors such as direct persecution of conflict-prone species. In this presentation we evaluate the different natural and anthropogenic drivers of human –wildlife conflicts as a means to find science-based and effective solutions that foster coexistence. We use the case study of brown bear (*Ursus arctos*) damages to human properties in the Polish Carpathians and in other European populations to illustrate how compensation programs, landscape features and forest productivity can influence the occurrence of damages at different temporal and spatial scales. At the continental scale, our findings emphasize the crucial role of proactive and preventive measures in reducing damage occurrence while evidencing that socio-cultural factors can heavily influence management policies and hinder conflict mitigation efforts. At the local scale, we deepen into the ecological drivers of conflicts and use spatial ecology, resource selection modeling, and remote sensing analyses to successfully predict the occurrence of bear damage in space and time. The results of our analyses show how natural resource pulses in human-dominated landscapes can percolate through food webs and impact human-wildlife coexistence. These studies provided clear

recommendations for reducing bear damages in the area and also offered a practical approach applicable in other places and to other species.

Keywords: *Human-wildlife conflict and coexistence, brown bear, Europe, Polish Carpathians*

Large carnivore monitoring and human-wildlife conflicts prevention in the Ukrainian Carpathians

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Understanding the conflicts that occur between humans and wildlife plays an important role in the conservation of large carnivores, effective management of their populations, as well as sustainable development of local communities in the Ukrainian Carpathians. Conflicts between humans and large carnivores are decisive for sustainable traditional farming practices (beekeeping, sheep farming, etc.) and for conserving viable populations of rare species of large carnivores in many regions of the Ukrainian Carpathians.

Monitoring of wolves, bears and lynxes, as well as monitoring of the number, frequency and spatial distribution of conflicts between large carnivores and farmers/beekeepers, was established in the framework of the implementation of WWF-Ukraine projects in the model regions of the Ukrainian Carpathians.

The "hot spots" of conflicts in the model territories of the Ukrainian Carpathians were identified, and conflict prevention tools, in particular electric fences, were popularized and implemented among local communities. As part of WWF-Ukraine projects, 36 electric fences were distributed to farmers and beekeepers to protect farms and prevent attacks by large carnivores, as well as 8 video stories about traditional and modern tools for coexistence with wild animals were created and distributed among stakeholders and media from 2019 to 2023.

Understanding the level of conflicts between humans and large carnivores in the region, as well as the number of large carnivores, will make it possible to implement effective measures to conserve rare species, manage their populations, and promote the development and preservation of traditional sustainable farming practices in the Ukrainian Carpathians.

Keywords: large carnivores, conflicts prevention, stakeholder engagement, conservation management, Ukrainian Carpathians

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Using of historical spatial data improves current species distribution models – case of the Carpathian brown bear

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Understanding the distribution of species of conservation concern is important to effectively maintain their populations under climate change and land-use transformation. To date, most species distribution models have relied on contemporary spatial data to describe and map habitat conditions. However, contemporary landscapes contain strong legacy effects that can play an important role in species' habitat selection and hence their distribution. In this study, we aimed to demonstrate the importance of land-use legacies in refining current patterns of habitat suitability by developing habitat distribution models for brown bear (*Ursus arctos*) in the eastern part of the Polish Carpathians. We compared three Maxent models of bear habitat suitability developed using a) contemporary spatial data only, b) historical spatial data only, and c) both contemporary and historical data. The comparison showed that the combination of contemporary spatial variables with historical information (e.g. indicating 150-year forest persistence, location of former settlements) performed best of the three approaches tested. Areas that have experienced rapid depopulation in the past now offer a range of habitat features (e.g., resources associated with fruit trees from former fruit orchards now embedded in the forest matrix) that would not be easily detected using contemporary land-use/cover data alone. More generally, our work shows that incorporating historical spatial data together with contemporary information can improve the explanation and mapping of current species distributions. This is particularly important for protected species, the conservation of which is critical to their successful management and recovery.

Keywords: *habitat modelling, historical spatial data, land use, brown bear, the Carpathians*

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Emergency-line calls as an tool to assess human-wildlife interactions in the Carpathian Mountains

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Human-wildlife interactions (HWI) are increasingly common as human disturbance as development continues to remove wildlife habitats. Documenting HWI's is critical for environmental protection agencies to develop strategies and management decisions that meet the needs of both people and wildlife. However, evaluation of frequency and types of HWI at broad spatial scales (e.g., national or regional level) can be costly and difficult to implement by managers. In this study, we apply a novel method for the evaluation of patterns of HWI in urban areas by using publicly available data from emergency calls placed by inhabitants of Romania's urban areas. We used information from 4,601 emergency calls placed at the Romanian National Emergency Call System 112, which consisted of (1) wildlife species, (2) spatial location, (3) date and time, and (4) a short description of the emergency. Out of the 318 analyzed cities, 300 cities documented emergency calls on HWI between 2015-2020, with roe deer and brown bear being the most frequently mentioned species. We recorded an increasing trend in HWI-related emergency calls in 73% of the urban areas over the five years period. We mapped the large-scale distribution of HWI by species and type of interactions in order to capture variations at the national level. Further, we analyzed the social and the biophysical factors potentially influencing the occurrence and frequency of HWI. The results showed that social factors have the same effect on all species, while the effect of the biophysical factors varied between species. Particularly, the presence of large natural habitats, represented by forests, influenced the number of calls only for brown bears. Seminatural landscapes with agricultural land have a different influence in terms of effect and significance for the considered species. Our results suggest that publicly available data from emergency calls can be used for the rapid assessment of HWI and for evaluating trends and predictors of HWI at broad spatial scales.

Keywords: human-wildlife interactions, emergency call, urban systems, human-wildlife conflicts, *Ursus arctos*.

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Impact of wildland-urban interface on human-wildlife interactions in the Polish Carpathians

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The wildland-urban interface (WUI) is an area where wild vegetation is close to settlements, which has many environmental and human implications. Although WUI mapping has typically been carried out in fire-prone areas, there is a need to monitor it also in other locations. According to recent research WUI existence may also support human-wildlife interactions, including disease transmission, wildlife damage to humans or competition for resources between domestic animals and wildlife. In this study, we used a set of detailed WUI maps of the Polish Carpathians to analyse their impact on the occurrence of damages caused by protected predators (wolves, bears, lynx). We found that although the proportion of WUI in the area does not directly explain the high number of damages, most of the damages occurred in WUI. We also found that a significant part of the damage took place in an area that had become a WUI many decades ago. This shows that the existence of a WUI has a strong legacy effect, also affecting human-wildlife interactions. There is a need for better spatial planning to avoid the creation of new WUI, especially in areas where large carnivores are recovering, in order to reduce the potential negative impact of their presence in highly developed, human-dominated landscape.

Keywords: land use, wildland-urban interface, WUI, large carnivores, the Polish Carpathians

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SUSTAINABLE TOURISM

Experience design and nature conservation via Visitor Monitoring and management in protected areas (VIMOMA)

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The 'Experience design and nature conservation via Visitor Monitoring and Management in protected areas - VIMOMA' project aimed to connect researchers and relevant stakeholders to make protected areas more efficient in nature conservation and visitor management in both Visegrad (V4) and Western Balkans (WB) countries.

The natural environment brings a range of benefits, such as relaxation, recreation, health, and socialising. Natural areas have always been popular destinations all over the world (Newsome 2002; Buckley 2010); nevertheless, visitor numbers in natural areas are undergoing steady increases — especially more so as an outcome of the pandemic, which rendered people in distinct degrees of confinement for an extended period of time — and such a trend may easily lead to overloading sensitive areas (Lebrun et al 2021).

Thus, VIMOMA aimed to address this problem by developing a framework methodology for visitor monitoring and management — an approach which is neither widespread nor much used throughout the V4 and WB regions.

Through the organisation of workshops and field trips in each of the five participating countries, the project gave an opportunity to professionals, policymakers, national park managers, and other stakeholders to share their experience and expertise, while also developing guidelines for visitor monitoring and shared, common positions related to appropriate Protected Area (PA) management.

The presentation will include results of the project and some practical recommendations for PA's management.

Keywords: Stakeholder engagement, Awareness-raising, Protected area management, Visitor monitoring, Nature-based tourism

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Profiling Sustainable Tourism Destination: Boykos' Carpathians project case

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Ukraine's tourism path within the framework of the Carpathian Convention before 2022 got additional impetuses from the progress in European Integration, administrative reform, and several positive shifts in tourism governance. The rude invasion failed to hamper the strive to recover based on the innovative approaches to tourism and recreation considered at the International Carpathian School 2023 – Ukraine (Carpathian Convention News, 2023). The latter inspired the collaboration of academicians and stakeholders of 12 local communities in the volunteer project initiated by the Ivano-Frankivsk oblast (region) of Ukraine and aimed to design a sustainable destination Boykos' Carpathians (Boikivski Karpaty in Ukrainian) (IFTourLand, 2023).

The idea of the project – to commence the destination development based on sustainability grounds and follow the vectors of European Integration – fits the objectives of the research topic Indicator Analyses of Sustainable Development in Ukraine (Kiptenko, 2019), providing the pioneer polygon to design the destination based on preliminary profiling of its sustainability.

The above task requested scrutinizing any relevant information reflecting the availability of data in order to contextualise locally the ETIS (EC, 2017) and the Carpathian Convention Tourism working group and projects outcomes (Interreg, 2021; OETE, 2017), involving the GSTC criteria (GSTC, 2019) and global approaches (UNWTO). The chamber period of research took advantage of data availability thanks to the positive results of the pre-war development of the national system of tourism statistics (NTOU, 2021) and the authorities' persistence in record keeping. The lack of systematic information on numerous indicative data challenges the comprehensive profiling of the destination. The ongoing preliminary surveys of stakeholders, media, and content analysis will eventually serve the feasibility of Boykos' Carpathians background sustainability profile.

Keywords: *sustainable tourism, destination profile, Carpathians, Boykos, Ukraine*

Acknowledgment: This work thanks to the support of the participants of the volunteer project "Boykos' Carpathians" initiated and led by Vitaliy Perederko, Head of the Tourism Department of the Department of International Cooperation, European Integration, Tourism and Investments of the Ivano-Frankivsk Regional State Administration, as well as colleagues and students of the Department of Regional Studies and Tourism of the Faculty of Geography of the Taras Shevchenko National University of Kyiv.

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Barriers and limitations to ski resort development in the Polish Carpathians in the opinion of ski resort operators

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Poland is among the group of European countries with the most well-developed ski infrastructure (Vanat, 2022). The most intensively developed tourist region for alpine skiing is the Carpathian Mountains, where 61% of the country's total ski infrastructure is located (Krzesiwo, 2023). Ski resorts are strategic business entities from the point of view of developing and shaping the tourist function during the winter season in mountain destinations. The income of the entire local economic sector, operating in conjunction with ski tourism, depends on their proper development and functioning. The purpose of the presentation will be to present the most significant barriers and limitations to the development of ski resorts in the Polish Carpathians from the point of view of the stability of ski resort operators as "growth machines" in local tourist reception systems. To achieve the research goal, questionnaire interviews were conducted with a group of 22 enterprises managing ski resorts in the Polish part of the Carpathian Mountains. Among the most serious barriers and limitations to the development of ski resorts are: high economic operating costs, including high real estate taxes, snowmaking costs and snow maintenance costs, cost of introducing innovations and the construction of new ski facilities, the consequences of complicated legal procedures on the implementation of new investments in ski resort infrastructure and the modernization of existing sites, instability of weather conditions in winter, seasonal revenue streams and staff shortages in the wintertime. The development of ski resorts and ski-dependent destinations is taking place against the backdrop of an ever-transforming tourism market and uncertainty about the size of operating revenues. Stability of development and competitive advantage in the long term will be gained by those ski resorts and ski tourist destinations that will be able to offer to a greater extent services complementary to skiing.

Keywords: *ski resorts, barriers of development, stability, Carpathian Mountains, Poland*

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Carpathian Long-distance Hiking Trail – Threat to Conservation or Chance for Sustainable Tourism?

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There have been several attempts of establishing a whole-Carpathian long-distance hiking trail. The contribution summarizes the attempts including the situation with the official E3 and E8 routes. Based on qualitative research among long-distance hikers, qualitative research conducted with Czech volunteer rangers, and recent quantitative research among protected landscape areas visitors it determines the main risks for conservation as well as potential for sustainable tourism. Exceptionality appeared to be the core variable in thematic analysis of long-distance hikers and their relationship to nature (conservation). This corresponds with visitor research findings as well as research among rangers which prove that (Czech) long-distance hikers are among the groups least willing to respect the conservation rules though being vocal in claiming their respect to nature. The contribution also summarizes needs of this type of tourists and analyses potential contribution to sustainable tourism based on two recently established long-distance hikes case studies.

Keywords: *long-distance hiking, Carpathians, conservation risks, qualitative research, sustainable tourism*

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Environmental carrying capacity index as a base for management of tourist traffic in mountain national parks – Karkonosze National Park case study.

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The key functions of national parks are to preserve natural phenomena and resources, provide access to them, as well as to conduct ecological education and research. Balancing the goals of nature conservation with tourist and sports activities objectives and providing access to natural resources should be regulated with the rules reflecting compromise on the growing needs for various forms of human presence in protected areas. Determining the threshold of nature protection requirements for minimizing the negative impact of tourism as well as sports activities is currently one of the most important challenges in national parks. Defined rules on access, including the activity types that could be undertaken, are the primary instrument for maintaining and controlling pressure on the protected and most sensitive parts of mountain ecosystems in national parks. For this purpose, Environmental Carrying Capacity Index (ECCI) has been developed, which expresses the natural resilience of the environment to degradation factors associated with tourist traffic. Research on the impact of various forms of activities on the ecosystems in the Karkonosze National Park (KPN) made it possible to identify a set of pressure factors expressed by the intensity of tourist, recreational, and sport activities in a specific area. Data of environmental monitoring were analyzed in order to recognize tourist traffic hot spots within the KPN in reference to core areas of the animals and working on the complex index for the ECC (incl. intensity of use of trails, proximity, and fragility indexes, intensity off-trail exploration, the density of trails per/area, regime of the conservation).

Consequently, a new approach to management will be implemented as a tool for the nature protection plan in KPN. It will include limitations in tourist traffic and tourist-flow scheme based on the Environmental Carrying Capacity Index and identified high-level impact of threats to preserve the natural resources of the park.

Keywords: *carrying capacity, national parks, tourism monitoring, tourist traffic, nature conservation*

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The succession dilemma in family tourist enterprises in the Polish Carpathians

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Depopulation, the transition of rural areas and the accompanying shifts in socio-ecological trends in urban settlements are recognized as contemporary social problems in the Carpathians (S4C Research Agenda, 2023). Recently, scholars identified a new social problem: the transfer of family tourism businesses to the next generation or the succession dilemma. Studies indicate that only half of the second-generation family businesses survive when the owner retires, and that only one-third survive into the third generation (Le Breton-Miller et al., 2004). This study takes on the succession dilemma of family tourist enterprises in the Podhale region of the Polish Carpathians. In the region under consideration, tourism is a factor of personal development, and the tourist function is treated as a factor of socio-economic development of the region (Diagnoza..., 2023). The study was carried out among family accommodation companies: guest houses, private accommodation facilities and agritourism farms. Observations from exploratory research show that, in traditional Carpathian communities and family-run tourism businesses, succession is an emerging dilemma, opening new research questions about, among others: the younger generations' interest in working in tourism, factors of continuing tourism business, the survival of family tourism businesses in the absence of a successor. Family ownership of a tourism business can act both as a demotivator and as a facilitator for the development of inherited tourism activities. According to their owners, accommodation companies are preparing for a generational change, and efforts are being made to maintain business continuity. Since the issue of succession can be delicate, and business owners rarely share this information, it is often assumed that this is a natural process. Presumably, the owners will defer their decision and that their heirs will simply inherit the business. Certainly, new generations of successors spend their lives in the tourist culture of the region. However, the question of future conditions and principles of a private tourist base owned by new generations in Podhale remains open.

Keywords: *succession, family tourism enterprises, generational change, Carpathians, Poland*

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