

Plastic residues in compost and potential additive release: implications for soil quality and plant exposure

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KEYWORDS: composting, microplastics, di-n-octyl phthalate

1 Introduction

Plastic bags introduced during biowaste collection may undergo physical breakdown during composting and become less conspicuous without being completely mineralized. This creates a difficulty for evaluating finished compost: successful decomposition of the organic feedstock can coincide with the persistence of synthetic polymer particles. If such compost is applied to soil, it may introduce plastic residues and, where present, releasable additives into the plant growth environment (Berta et al. in press, 2026).

This focused review synthesizes findings from two complementary studies to which we contributed. The composting study (Berta et al. in press) examined plastic fragmentation and residual polymers, while the microcosm study [2] investigated DnOP release from PVC and its effects on white mustard. Together, these findings provide a basis for evaluating a potential environmental pathway from plastic disintegration to additive release and plant exposure. Physical disintegration, chemical release and biological uptake are considered separately, as evidence for one process does not necessarily establish the others. The composting article has been accepted for publication and is cited as in press (Berta et al. in press).

2 Plastic disintegration and residual polymers in compost

The composting study comprised three investigations: a conventional PE green-waste collection bag treated for 90 days in a drum composter; commercially available bags marketed as degradable or compostable treated for 180 days in an outdoor household compost pile, and finished compost from a full-scale municipal green-waste facility (Berta et al. in press). The drum experiment reached a maximum temperature of 50–55 °C. The outdoor experiment exposed the materials to natural precipitation, solar radiation and temperature fluctuations. These treatments represent different operating conditions and should not be interpreted as equivalent tests of compostability.

Following the 180-day outdoor treatment, the original bags were no longer macroscopically recognizable. Nevertheless, FTIR analysis detected PLA-based particles in the recovered microplastic fraction. Their spectra retained the characteristic ester carbonyl band near 1750 cm⁻¹ and diagnostic bands in the fingerprint region. Changes in hydroxyl-region absorption and relative band intensities were consistent with alteration during composting, although moisture and attached organic matter could also contribute. The persistence of polymer-specific bands demonstrates residual PLA and shows that visible disappearance did not establish complete mineralization (Berta et al. in press).

The commercial bags were composted together, so recovered particles could not be attributed unequivocally to individual brands. Some initial materials were identified as predominantly PE, illustrating the need to verify composition rather than infer it from commercial degradation claims. The municipal compost investigation identified PET in a red fragment and PE in a green fragment. These observations establish the presence of residual polymers in finished compost, although the study did not report a standardized particle abundance or a polymer-carbon mass balance (Berta et al. in press).

Interpretation of the FTIR results from the drum experiment is complicated by overlapping spectral features. A recovered fragment exhibited amide-related infrared bands tentatively assigned to polyamide 66, but these overlapped with bands characteristic of keratinaceous material. The overlapping bands do not allow an unequivocal assignment to polyamide 66, highlighting the need for spatially resolved analysis. They also provide no evidence that the original PE bag was converted into another polymer. Sample preparation involved peroxide digestion, decantation, NaBr density separation and quartz filtration, with reported limitations related to fine-particle loss and spectral interference (Berta et al. in press).

3 DnOP release from PVC

The direct evidence for DnOP release comes from a separate experiment using 2 × 2 cm PVC shrink-wrap pieces. Berta, Babos and Karlik (2026) compared PVC exposed without water or soil, in water, and in moistened soil. All treatments involved UV exposure at 35 °C, with measurements after one, three and six months and three replicates. These were controlled ageing treatments rather than thermophilic composting experiments. Consequently, they demonstrate release under the tested conditions without directly quantifying DnOP release during the composting treatments examined in the composting study.

4 Release dynamics and environmental interpretation

The water treatment yielded the highest reported DnOP concentrations, increasing from 44.50 µg/L after one month to 60.43 µg/L after six months. The soil treatment yielded 10.94, 10.71 and 14.41 µg/L at the corresponding sampling times. In the treatment without water or soil, the reported concentration increased from 13.99 to 45.25 µg/L (Berta et al., 2026). These results indicate that the surrounding matrix influenced the measured DnOP concentration. The soil-treatment values were reported in µg/L and therefore cannot be directly interpreted as soil concentrations in mg/kg.

The lower concentration measured in the soil treatment is compatible with stronger retention within the matrix, as proposed in the microcosm study (Berta et al., 2026). It does not, by itself, demonstrate complete removal or degradation of DnOP. Establishing the distribution among plastic, soil solids and water would require a mass balance and clearly defined extraction recoveries. Likewise, the increasing concentration in the water treatment supports continuing release or accumulation, but it cannot be converted into a release rate without the relevant volumes and initial additive inventory.

Taken together, the findings suggest that residual plastic particles could provide an ongoing source of additives where their formulation contains releasable compounds. However, the identified PLA, PE and PET residues were not analysed for DnOP (Berta et al. in press). The release behaviour observed for PVC does not establish DnOP release from the recovered bag fragments. Polymer identity and additive composition must both be established before attributing a specific chemical exposure to compost-derived particles.

5 Plant uptake and growth responses

The microcosm study used white mustard grown in a mixture of equal amounts of garden soil and green-waste compost. Pots contained 300 g of substrate, and four seeds were planted per

pot, with three replicates for each DnOP treatment. DnOP was introduced using nominal dosing solutions of 100, 150 and 200 mg/L, prepared with ethanol to aid dissolution and subsequently diluted with water. The solvent was allowed to evaporate before sowing, and no additional DnOP was applied during cultivation (Berta et al., 2026).

Germination was delayed in the exposed treatments. On day 12, control plants were 5.5 cm tall, compared with 4 cm in the 100 and 150 mg/L treatments and 3 cm in the 200 mg/L treatment. The highest treatment therefore showed an approximately 45% reduction in height relative to the control at this early observation point. By day 30, exposed plants remained shorter, and flowering was observed and interpreted as a stress-related response. No distinct morphological abnormalities were reported, indicating that measurable growth effects can occur without obvious structural deformities (Berta et al., 2026).

GC-MS analysis detected DnOP in plant material, with tissue concentrations increasing with nominal exposure (Berta et al., 2026). These results support plant-associated accumulation under the experimental conditions, although root-to-shoot transport, intracellular distribution and the specific uptake mechanism remain unresolved. Accordingly, this review discusses the qualitative accumulation trend without reproducing those percentages or calculating a bioconcentration factor.

6 Linking compost contamination to plant exposure

The combined evidence supports a plausible sequence in which plastic-containing biowaste undergoes composting, residual particles remain in the finished material, and land application introduces those particles into soil. Where the particles contain DnOP, release could then contribute to exposure in the root environment. The PVC ageing experiment demonstrates the release step for one tested material, and the mustard experiment demonstrates plant accumulation following direct DnOP amendment (Berta et al. in press, 2026). Neither study followed DnOP from a specific composted bag into the tissues of a subsequently cultivated plant.

The two experiments also differed substantially in exposure concentration. The highest reported water-treatment concentration was 60.43 µg/L, equivalent to 0.06043 mg/L, whereas the plant dosing solutions contained 100–200 mg/L. Nominal dosing concentrations were therefore approximately 1,650–3,310 times higher than that measured water concentration. This difference highlights the exposure gap, although dosing-solution concentration, soil loading and porewater concentration represent different quantities and do not permit a direct comparison of actual root-zone doses. The plant experiment demonstrates responses at the tested exposures, but does not establish the same responses at the measured leachate concentrations (Berta et al., 2026).

These findings provide a basis for further investigation of agricultural exposure, while their implications for crop performance and food safety remain to be established. Effects on sulfur assimilation, glucosinolate composition, nutritional quality and harvested yield were identified as questions for further research but were not measured (Berta et al., 2026). Similarly, DnOP detection in mustard does not establish human absorption or quantify dietary risk. Further evidence is therefore needed to assess the environmental and food-chain implications of the observed plant accumulation.

7 Research needs and conclusions

A direct test of the proposed pathway should determine the initial DnOP content of each plastic formulation, quantify polymer residues and DnOP throughout composting, and then cultivate plants in the resulting compost-amended soil. Measurements should distinguish total extractable DnOP from porewater concentrations and separate roots from shoots and edible tissues. Procedural blanks, recovery controls and adequate biological replication would help

establish whether observed residues arise from the tested materials and whether they correspond to reproducible growth effects. Exposures should include concentrations measured in the actual compost and soil system.

The two studies show that plastic disintegration can leave identifiable polymer residues in compost and that DnOP can be released from PVC and detected in exposed white mustard (Berta et al. in press, 2026). Together, these findings suggest a potential connection between organic-waste management and chemical exposure in plants. Further experiments tracing this pathway within a single system are needed to establish the connection. Compost evaluation should therefore extend beyond visible plastic removal to polymer identification and, where relevant, additive-specific measurements.

Acknowledgement

Projects no. 2022-1.1.1-KK-2022-00002 and 2025-2.1.1-EKÖP-2025-00029 have been implemented with support provided by the Ministry of Culture and Innovation of Hungary from the National Research, Development and Innovation Fund, financed under the 2022-1.1.1-KK and 2025-2.1.1-EKÖP funding schemes.

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Connecting Sectors and Scales through Climate Services for Resilient Cities and Forests – Insights from CROSSEU, CARMINE and OptFor-EU

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Climate change affects urban populations, infrastructure, water resources and forests simultaneously, yet adaptation decisions are often made within separate sectors and across disconnected spatial scales. This contribution synthesises emerging results from three Horizon Europe projects coordinated by Romania, (i.e., CROSSEU, CARMINE and OptFor-EU), to demonstrate how co-produced climate services can bridge these divides.

CROSSEU integrates climate, biogeophysical and socio-economic information to assess cross-sectoral risks, regional hotspots and adaptation trade-offs. Its harmonised datasets, integrated assessment framework and decision-support prototype support evidence-based policy and investment choices. CARMINE bridges metropolitan and neighbourhood scales by combining high-resolution risk modelling, eight Living Labs and emerging digital twins. These tools facilitate co-designed responses to urban heat, flooding, water scarcity and other hazards, including nature-based solutions. OptFor-EU links Europe-wide climate and forest modelling to practical forest management in regional case studies. It has validated Essential Forest Mitigation Indicators and developed a decision-support prototype to compare management scenarios, ecosystem services and carbon outcomes under changing climates.

Across the three projects, the findings point to common requirements for effective climate services: consistent information across scales, integration of connected sectors and sustained engagement with practitioners and policymakers. The presentation highlights opportunities to connect urban and forest systems through shared concerns such as water regulation, heat stress, biodiversity and carbon sequestration, while making uncertainties and adaptation-mitigation trade-offs explicit. Together, these approaches help turn climate knowledge into coordinated, place-based decisions for more resilient cities, climate-smart forestry and European decarbonisation.

Holocene environmental changes in the Svydovets Massif (Ukraine): A multi-proxy record from Ozero Velyke peatland

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KEYWORDS: Holocene, Svydovets Massif, Ukrainian Carpathians, Ozero Velyke, peatland, timberline, erosion, geochemistry, human impact

The Ukrainian Carpathians remain one of the least investigated regions of the Carpathian arc in terms of high-resolution Holocene environmental change. Here, we reconstruct the environmental history of the Ozero Velyke lake–peatland system in the Svydovets Massif using a multi-proxy record combining pollen, micro- and macrocharcoal, sediment lithology, geochemistry, stable organic-matter indicators and radiocarbon dating. The ca. 9.5 ka record documents four major stages of ecosystem development. Initially, a shallow lake developed under generally humid conditions, interrupted by short-lived dry episodes and phases of enhanced fire activity. Between ca. 6.8 and 5.6 ka, progressive lake shallowing and increased terrestriation culminated in an abrupt transition from lacustrine to peat-forming conditions at ca. 6.5 ka, associated with regional hydroclimatic reorganisation and mid-Holocene drying. From ca. 4.5 ka, the system became strongly buffered, with persistent waterlogging, organic sediment accumulation and very low clastic input, indicating a resilient peatland largely decoupled from catchment erosion. Vegetation data further indicate that the Holocene timberline in the Svydovets Massif was substantially higher than today, with trees and shrubs occurring at ca. 1620–1670 m a.s.l. during the Early Holocene. Short-lived destabilisation occurred during Late Antiquity, when enhanced runoff and erosion temporarily interrupted peat accumulation. During the Little Ice Age, hydroclimatic variability, erosion and changes in peat-forming vegetation increased, while the most recent sediments record renewed minerogenic input and atmospheric deposition, including elevated Hg content.

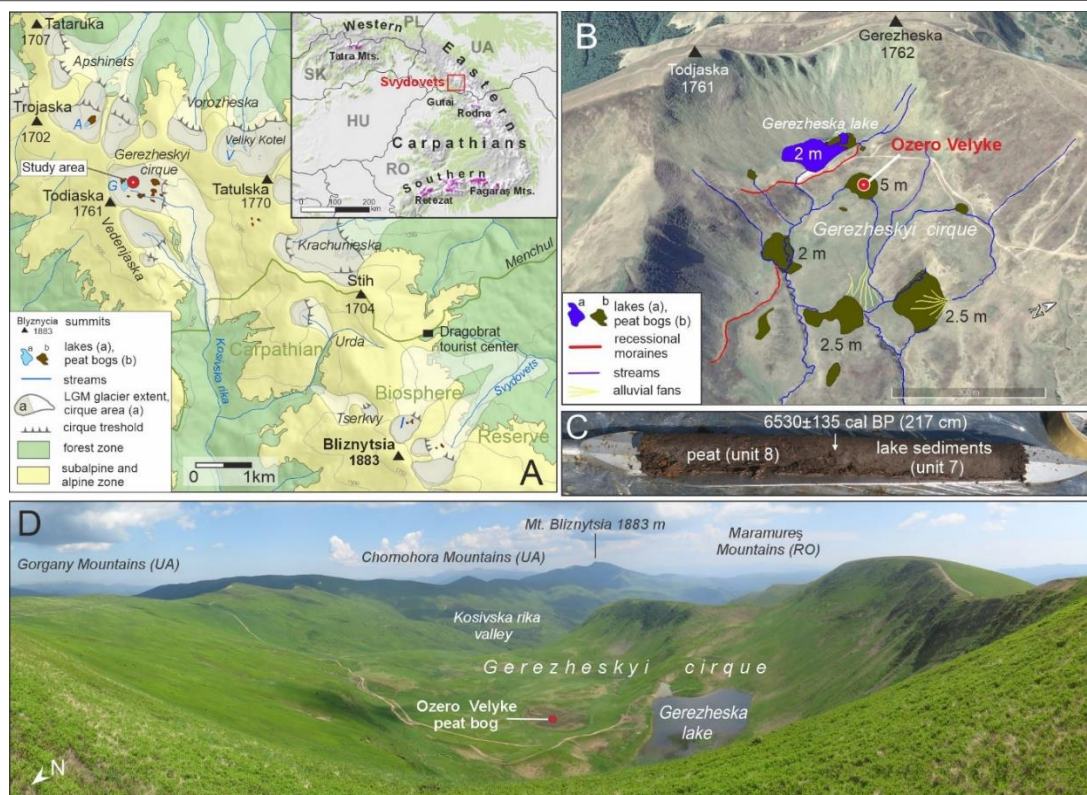


Figure 1 Location of the Ozero Velyke site. A – Location of the peat bog within the Svydovets massif and the Carpathians. Abbreviation indicate glacial lakes: A – Lake Apshinets, V – Lake Vorozheska, G – Lake Gerezheska, and I – Lake Ivor. B – Google Earth view of the Gerezheskyi cirque showing the location of the Ozero Velyke site and the main geomorphological features within its catchment. The maximal thickness of sediments was marked. C – Distinct lithological boundary between lacustrine mud (Unit 7) and peat (Unit 8), marking the transition from the limnic to the peat-forming phase of Ozero Velyke development at ca. 6.5 ka. D – Panoramic view from the ridge of Mt. Todiaska. The coring location within the Ozero Velyke peat bog is marked with a red dot.

The palaeoenvironmental record of the Pleistocene sections in the eastern and western Carpathian foothills (Ukraine)

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KEYWORDS: pedostratigraphy, pollen, climate, environmental reconstructions

Lithopedological and pollen studies of loess-palaeosol, cave and alluvial deposits in the Tyssa Lowland, the eastern Carpathians and the Middle Dniester area, supported by OSL- and ^{14}C chronology, form the bases for palaeoenvironmental reconstructions. The names of time units used in this research follow the nomenclature of the Pleistocene framework of Ukraine (Veklich, Ed., 1993), but their chronological positions are in part changed, because of new palaeomagnetic and pollen data. The M/B reversal was shown to be at the base of the Shyrokyne unit (Glavatsky, Bakhmutov, 2020). The oldest deposits are represented in the Korolevo I site by alluvium (Adamenko, Gladilin, 1989; Koulakovska et al., 2010), dated to 1.4 Ma (Garba et al., 2024), that corresponds to the **Kryzhanivka** unit. At the Gat' section (the Tyssa Lowland), this unit is the pedocomplex of red-coloured, leached of CaCO_3 , rich in Fe_2O_3 clayey soils, resembling subtropical ferruginous soils though less weathered than in typical subtropics (Gerasimenko, Vozgrin, 2011). They developed first under open-canopy woodland (*Quercus*, *Tilia*, *Acer*), with some subtropical trees, and then under shadow *Ostrya*-*Fagus*-*Carpinus* forest. The next **Illichiv** times had severe climate, when input of coarse silt increased, preventing soil profiles development, broad-leaved trees disappeared and forest-steppe occupied the area. Palaeosol and pollen data from the next **Shyrokyne** pedocomplex indicate a strong aridification trend to the late part of the unit. The lower soils (sh_1) were Chromic Luvisols formed under *Carpinus*-dominated forest, with admixture of warmth-loving *Juglans*, *Pterocarya* and *Carya*. The upper, less weathered soils (sh_3) are similar to Vertisols, rather rich in humus and MgO . They developed under warm sub-humid to sub-arid climate in open environments, with the growth of some subtropical trees (*Rhus*, Moraceae). The position of Brunhes- Matuyama boundary within the Shyrokyne unit in the key localities of Ukraine allows its correlation with the MIS 19 and MIS 17. The thin loess between the soils must correspond to MIS 18.

Five main stages of environmental development occurred between the Shyrokyne times and the Lower Zavadivka interglacial: the Korolevo I (Koulakovska et al., 2010), Gat' (Gerasimenko, Vozgrin, 2011), Ruban and Sokyryntsia sites (Gerasimenko et al., 2019) in the Tyssa Lowland, the Deliatyn and Drybka sites (Gerasimenko, 2024) in the eastern Carpathians. The Lower Zavadivka interglacial has repeatedly been proven (using small mammals, snails, pollen) to be the equivalent of the Holsteinian interglacial/MIS 11. Earlier, the Martonosha and Lubny interglacials and the Pryazov, Sula and Tyligul cold periods occurred. The two reddish-coloured Chromic Cambisols of the **Martonosha** pedocomplex (MIS 15) formed under similar environments. They were less clayey, leached of CaCO_3 , poorer in humus and richer in Fe_2O_3 than the Shyrokyne soils. The typical vegetation was light pine woodland (*Pinus Strobus*), including broad-leaved trees (particularly *Carpinus* and *Tilia*) and few highly thermophilous species. The climate was transitional from warm-temperate to subtropical, warmer and wetter at the first half of the stage. During **Lubny** times, two soils of temperate climate formed. Yellow-coloured Luvisols of warm facies developed under mixed forest. First, *Pinus*, *Quercus*

and *Tilia* dominated; then, broad-leaved taxa became more diverse (*Carpinus*, *Fagus*), but the areas of open landscapes (mesophytic herbs) increased. *Picea* became abundant at the end of this interglacial. Generally, the climate was less warm than that of the preceding interglacials, and it corresponds to the cooler climate of the MIS 13. The **Pryazov** loess formed under boreal grass-sedges associations, with few groves of trees (including *Tilia*), whereas the thick **Sula** loess accumulated in subperiglacial steppe, with small admixture of arcto-boreal plants. The **Tyligul** cold period was marked by a mozaic of boreal woodlands and mesophytic steppe. Ferns grew abundantly in the Tyssa Lowland, and *Sphagnum* bogs occupied large areas in the eastern Carpathian foothills. Cryoturbations on a small scale developed during the Sula and Tyligul times. At Korolevo I, Early Palaeolithic artefacts were found in the the above-mentioned interglacial units but not in the deposits of cold periods (Koulakovska et al., 2010).

Two interglacials came between MIS 11 (Lower Zavadiivka) and MIS 6 (the Dnipro glaciation in Ukraine (Gerasimenko, 2024). Their deposits can be traced at Korolevo I, Gat' and Drybka sites. The two interglacials were separated by cold periods (the **Middle Zavadiivka** and **Oril**), when non-soil deposits formed, cryoturbations developed, and a cold steppe existed. MIS 11 (the **Lower Zavadiivka**, with the Holsteinian pollen succession, had a warm-temperate climate, reflected in the weathering indices of its Luvisols and in the presence of warmth-loving species (the Neogene relics) including *Pterocarya*. The next interglacial (the **Upper Zavadiivka**, MIS 9) included two Luvisols of the climatic optimum, followed by a less developed humic interstadial soil. The Luvisols formed under forests dominated by *Carpinus* and *Quercus* in the Tyssa Lowland, *Carpinus* and *Fagus* in the higher localities of the eastern Carpathians. *Picea* and few *Abies* were present, whereas highly thermophilic trees absent. The climate was less warm than during the preceding interglacial but wetter than nowadays. Ferns were very abundant in the Tyssa Lowland. The next **Potiagailivka** interglacial (MIS 7) had a temperate climate, with Luvisols being developed under forests from *Pinus*, *Quercus* and *Fagus* in the Tyssa Lowland and from *Picea*, *Abies*, *Quercus* and *Fagus* in the eastern Carpathians. The migration down of conifer trees belt demonstrates the further climatic cooling, as well as smaller weathering indices than in the preceding interglacial soils. The **Dnipro** periglacial stage was marked by the thickest loess accumulation, cryoturbations and the mozaic vegetation: pine-birch groves, mesophytic steppe and arcto-boreal plants including *Betula* sect. Nanae et Fruticosae (the Gat', Sokyrhytsia and Drybka sites). In the Middle Dniester area (the Neporotove 7 site) at the beginning of the Dnipro stage, climatic fluctuations are documented in alternation of loesses, formed under tundra-forest-steppe, and incipient soils. The latter developed under boreal forest-steppe: *Betula-Pinus* forests (with admixture of *Picea*, *Larix*, few *Corylus*) and mesophytic herbal coenoses (Koulakovska et al., 2021). At the end of the stage (OSL >120 ka, TL 150±20 ka), dry *Artemisia*-Poaceae steppe was established. The Dnipro loess corresponds to the first cold unit in the Tyssa Lowland and the Middle Dniester area, in which cultural horizons were found.

The pollen succession of the last interglacial (MIS 5e), marked by the Blake episode at the bottom (Adamenko, Gladilin, 1989) is recorded in the **Kaydaky** Luvisols (the Sokyrnytsia, Delyatyn, Gat' and Korolevo I sites), as well as in the cave deposits of the Tovtry site (Gerasimenko et al., 2016) and Neporotove 7 in the Middle Dniester area. The peculiar feature of this succession in the Transcarpathia is the presence of *Fagus* pollen during the temperate stage of the interglacial. In the Middle Dniester area, *Picea* is characteristic for its pre-temperate stage. In all studied areas, the MIS 5 also includes soils of two interstadials (**Pryluky 1 and 3**) and thin non-soil beds of two stadials (**Tiasmyn** and **Pryluky 2**). In the Transcarpathia and in the mountains, all Pryluky soils are Luvic Cambisols, whereas in the Middle Dniester area, the lower one (MIS 5c) is a Retisol, and the upper one (MIS 5a) is a carbonated chernozem. The cold Tiasmyn unit (MIS 5d) was formed under tundra-steppe. The ground wedges opened from this level, and cryolamination developed in the underlying

soils, all indicating a periglacial climate. Pryluky 1 (MIS 5c) soils and pollen give evidence of forest and forest-steppe environment of a south-boreal climate. Broad-leaved trees occurred in the woods, dominated by *Pinus* and *Betula*. Cryoturbations developed in the tundra-steppe of the periglacial Pryluky 2 times (MIS 5b). During the Pryluky 3 times (MIS 5a), boreal forest covered the Transcarpathia, whereas mesophytic steppe with few birch-pine groves occupied the Middle Dniester area. The Middle Palaeolithic cultures existed at Sokyrnytsia and Neporotove 7 during the time, corresponding to MIS 5.

Loess accumulation and very deep cryogenic wedging developed under periglacial steppe during the **Uday** stadial (MIS 4, TL 60±8 ka), the time when the Middle and Upper Palaeolithic cultures co-existed in the Transcarpathia, but only Middle Palaeolithic occupation occurred in the Middle Dniester area (Koulakovska et al., 2010, 2021). Nevertheless, the episode of warmer climate is recorded in some valley and mountain refugia when broad-leaved species (*Tilia*, *Corylus*) grew in small numbers (Yurchenko, 2017; Gerasimenko, 2024). During the the **Vytachiv** times (MIS 3, ¹⁴C from 43,166±300 ka to 28,570±160, 30,593±320 ka), 2-3 interstadial soils were formed, with thin loess beds of the stadials in between. The mildest climate existed when the lower Eutric Cambisols developed under mixed forest from *Pinus* and *Picea*, with admixture of *Quercus*, *Carpinus*, *Ulmus*, *Tilia*, in the mountains and hills (the Bukovynka site) of *Abies* and *Fagus*. Broad-leaved trees were more common in the Tyssa and Dniester valleys. Gleying processes were most frequent in these soils. The upper Cambisols were more humified and formed under forest-steppe of south-boreal and more continental climate, with lesser participation of broad-leaved species in the vegetation, and disappearance of dark-coniferous trees. During the Vytachiv stadials, sparse *Pinus* forest, with shrub *Betula*, xerophytes and cryophytes in the ground cover spread, turning into tundra-steppe in the higher topographical localities. Ground wedges and involutions of the Vytachiv stadials were dense, but did not penetrate down deeply. The relatively thick **Bug** loess (MIS 2) accumulated under periglacial mesophytic steppe. Several incipient soils developed during the first half of this stage, between ¹⁴C 25.3 and 20.5 ka, being particularly noticeable in the Molodova V and Doroshivtsi site in the Middle Dniester area (Haesaerts et al., 2020). Some of these soils, especially between 20.5 ka and 21.0 ka, are tundra-gleys, formed under tundra-steppe and tundra-forest-steppe, but some are primitive Cambisols, which developed under boreal forest-steppe, with few *Tilia* and *Corylus*. The best developed humified Cambisol, formed around ¹⁴C 19 ka under boreal mesophytic steppe, corresponds to the **Dofinivka** interstadial. The uppermost part of the Pleistocene section is represented by a typical loesses of the **Prychernomorsk** stadial, which was characterized by more xeric steppe than that of the Bug times. Few humic incipient soils within the Prychernomorsk unit (between ¹⁴C 17.6 ka and 15.5 ka) developed under boreal steppe and forest-steppe vegetation, whereas the growth of arcto-boreal plants during the accumulation of the Prychernomorsk loesses indicates a periglacial climate. The cryostructures were more expressive during the first half of MIS 2 (the Bug times).

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Chironomid assemblages from Eastern Carpathian alpine lakes: driving factors and implications for palaeolimnology

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KEYWORDS: non-biting midges, mountain lakes, acidity, elevation, surface-sediments, autecology

The Carpathians are an important European biodiversity hotspot, yet the aquatic biota of the Eastern Carpathians remain comparatively poorly studied. To address this knowledge gap, we analysed subfossil chironomid assemblages in surface sediments from 27 lakes of four neighbouring mountain massifs in Ukraine (Chornohora and Svydovets Mountains) and Romania (Maramures and Rodna Mountains) and assessed their relationships with environmental variables. We identified over 60 chironomid morphotypes, with *Procladius*, *Tanytarsus lugens*-type, *Paratanytarsus penicillatus*-type and *Chironomus anthracinus*-type being the most common taxa. Assemblage composition differed significantly between Ukrainian and Romanian lakes, whereas differences among massifs within each country were not significant, suggesting an important influence of geographical proximity. Ukrainian lakes were characterized by thermally plastic and acid-tolerant taxa, whereas Romanian lakes harboured some cold-stenothermic taxa. Altitude and pH were the main drivers of assemblage composition, but local hydrological processes modified these gradients. Comparison of subfossil morphotypes with their contemporary counterparts in regional water bodies further showed that morphotype-specific ecological associations may vary geographically because of differences in the underlying species composition.

Acknowledgement

The study was supported by the Slovak Research and Development Agency, project No. APVV-20-0358.

Improving European reforestation potential estimates to support climate mitigation and biodiversity

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Tree-planting initiatives, as a nature-based solution to mitigate climate change by enhancing carbon sequestration, have become a central focus of many conservation and restoration strategies, including the 2030 Biodiversity Strategy under the European Green Deal. Misidentifying areas for reforestation in various reforestation initiatives raises concerns regarding inappropriate afforestation of vegetation types with low tree cover, such as natural and seminatural grasslands, forest-steppes, and woodlands. Here, we address spatial inadequacy in forest restoration recommendations in Europe by adopting a stricter definition of forest cover and recognizing woodlands as a distinct forest category from closed forests. Our preliminary results show that the highest uncertainties in forest recommendations were in areas covered by open and semi-open vegetation types and that our approach reduces inconsistencies in separating forest from open vegetation. We emphasize the importance of carefully evaluating which areas are both feasible and appropriate for reforestation, considering local ecological contexts.

Strategic for Whom? A Critical Perspective on the exploitation of Critical Raw Materials in Romania

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KEYWORDS: Regulation (EU) 2024/1252, Critical Raw Materials Act, green transition, environmental journalism, copper, magnesium

Regulation (EU) 2024/1252, the Critical Raw Materials Act (CRMA), adopted in April 2024 and in force since May 2024, aims to secure the European Union industry's access to raw materials deemed critical and strategic for the transition to a green industry and economy (renewable energy generation, batteries, electric vehicles, semiconductors, digitalization, defense). Its primary objective is to reduce the EU's dependence in this area on non-European countries, particularly China.

This case study examines how the implementation of the CRMA in Romania served as a pretext for favouring politically controlled and/or politically connected projects. The Regulation was invoked to justify a legislative initiative that goes beyond its scope. The initiative contains provisions that circumvent environmental protection laws and restrict, to the point of eliminating, the rights of local communities: the right to property, the right to a healthy environment, and access to justice. Moreover, at least in the case of the most advanced project, there is no real guarantee that the raw material will not end up in China, only to be re-exported to the EU as finished products.

The study covers four projects: Rovina (Hunedoara County; gold and copper), Budureasa (Bihor County; magnesium), Baia de Fier (Gorj County; graphite), and Rășinari-Săliște (Sibiu County; production of magnesium metal from serpentinite). The first three were selected as Strategic Projects under the CRMA by the European Commission in 2025, while the fourth is seeking the same status.

Modelling the evolution of soil organic carbon in Romania under erosion impact and different climate change scenarios

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KEYWORDS: soil organic carbon, evolution, erosion, Romania

In addition to its influence of soil fertility, soil organic carbon plays an important role in current climate change, serving both as source of atmospheric carbon and as carbon storage. Consequently, knowing the spatial and temporal dynamics of soil organic carbon is essential for evolutive models of soil fertility and climate change. Our study aims to model the spatial and temporal dynamics of soil organic carbon in Romania in the upper 20 cm of soil starting from present time (2015) until 2050 and 2070 under two climate change scenarios (RCP 4.5 and RCP 8.5). Our approach is based on coupling an evolutive organic carbon model (AMG) with an erosion model (RUSLE). The starting point was the current (2015) soil organic carbon reserve in the top 20 cm of soil, derived based on the LUCAS database. The evolutive AMG model considers the manifestation of bioaccumulation, humification and mineralization processes, while the erosion model considers the influence of pluviometric (rainfall erosivity), geomorphometric (slope, slope length), soil (erodibility), biogeographic (land use/cover) and anthropic (erosion control measures) factors. The application of the coupled model allowed us to map the regions in Romania displaying high risk of regressive evolution of soil organic carbon as a consequence of either erosional processes or intensification of humus mineralization because of climate warming, or due to both processes. These region are situated mainly in the Transylvanian Depression, Subcarpathians, Moldavian Plateau and Dobrogea Plateau.

Hydrometeorological Warnings and their impact on the road network of the Republic of Moldova (2016–2025)

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KEYWORDS: meteorological warning, meteoalarm, roads, pluvial flooding, snowfall, vulnerability, Republic of Moldova, GIS, impact-based forecasting

Meteorological warnings represent the key link between atmospheric observation, weather forecasting, and the operational decisions made by institutions responsible for public safety and the functioning of infrastructure. For road networks, the value of a warning depends not only on forecast accuracy, but also on the capacity to translate information on wind, precipitation, snowfall, black ice, fog, heatwaves, or floods into concrete actions, such as preparing maintenance equipment, temporarily restricting traffic, inspecting bridges and culverts, mobilizing emergency response teams, informing drivers, and selecting alternative routes. In the Republic of Moldova, these processes are particularly important because the road network crosses a fragmented relief, small river basins with rapid responses to heavy rainfall, floodplains of the Prut and Dniester rivers, and urban areas where extensive surface sealing promotes the rapid accumulation of stormwater.

The period analyzed in this article is 2016–2025, corresponding to the last ten complete calendar years preceding 2026. The choice of 2016 as the starting year also has institutional significance: the State Hydrometeorological Service reported that the Republic of Moldova joined the European Meteoalarm community that year, after which warnings began to be distributed to the European platform in the interoperable Common Alerting Protocol (CAP) format. The national colour-coded warning system had been operational since 2010; however, integration into the Meteoalarm framework strengthened both the comparability and cross-border dissemination of warning information. From an operational perspective, the 2016–2025 period includes both events with immediate effects on road traffic—heavy snowfall, blizzards, torrential rainfall, hail, strong winds, fog, and icy road conditions—and slow-onset phenomena such as drought and extreme heat, which can deteriorate road embankments, contribute to pavement cracking, and increase the risk of vegetation fires in areas adjacent to roads.

The general objective of the research is to develop a critical statistical assessment of publicly documented meteorological warnings for the 2016–2025 period and to correlate them with reported impacts on the road network. Five specific objectives are pursued: inventorying national and international data sources; assessing the completeness of the meteo.md and old.meteo.md archives; classifying warnings according to hazard type and relevance to road infrastructure; calculating statistical indicators for the years for which official totals are available; and identifying the regions and types of road corridors that experienced greater impacts. The analysis does not equate the number of warnings with the number of disasters. A warning is a forecasting product, whereas a disaster is a realized event defined by its consequences. Moreover, a single synoptic situation may generate several updates or successive warnings, while a nationwide warning may cover several districts without producing the same intensity of impact in each of them.

The main difficulty of the research is the incomplete nature of the publicly accessible archive. The archive page of the current www.meteo.md website contains template-type elements and does not provide an exhaustive, searchable catalogue of all historical warnings. The old.meteo.md version preserves numerous bulletins, hydrological yearbooks, and operational pages; however, these materials are dispersed, follow different formats, and do not constitute a single integrated database. In addition, the published link for the 2024 activity report redirects to the document for 2023.

This methodological approach is essential for ensuring the credibility of the results. A ten-year series constructed by combining official annual totals with partial manual counts would create a misleading impression of data homogeneity. By contrast, distinguishing between confirmed annual totals, category-specific warning profiles, and documented impact events makes it possible both to conduct statistical analysis and to identify institutional data gaps. The resulting study is therefore not merely a climatological synthesis, but also an assessment of warning-data governance, with direct relevance to the development of a national impact-based forecasting system and to research on the vulnerability of road infrastructure.

Acknowledgement

This study was conducted with the support of the National Agency for Research and Development of the Republic of Moldova under the project "Vulnerability of road infrastructure and the population to climate risks: solutions based on data science and space research," project code 25.80012.7007.27SE.

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Spatial changes in climate types across Ukraine in the 20th–21st centuries: based on the Köppen–Geiger classification

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KEYWORDS: climate change, Köppen-Geiger classification, spatial transformations, Ukraine, agroclimatic impact

Contemporary climate change is manifested not only in rising air temperatures and changes in the amount and seasonal distribution of precipitation, but also in the transformation of the spatial structure of climate types. Such changes are particularly important for Central and Eastern Europe, where the interaction of Atlantic and continental air masses, considerable orographic heterogeneity, and the presence of the Carpathian mountain system create a complex mosaic of climatic conditions.

Ukraine occupies a substantial part of the eastern sector of Central and Eastern Europe and is characterised by considerable spatial heterogeneity of climate resulting from a combination of factors. Identifying changes in the boundaries of climate types makes it possible to provide an integrated assessment of long-term changes in temperature and moisture regimes, while also identifying areas where transformations of the climate system may already be affecting natural ecosystems and human activities.

The aim of this study is to determine the spatiotemporal transformations of climate types across Ukraine during 1901–2020 according to the Köppen–Geiger classification and to identify the main directions of shifts in their boundaries.

The theoretical framework of the study is the Köppen–Geiger climate classification, which uses annual patterns of temperature and precipitation and makes it possible to clearly identify climate types and trace changes in their boundaries over time. The primary source of cartographic data was a global high-resolution dataset with a spatial resolution of 1 km (Beck et al., 2023). Four 30-year climatic periods were selected for comparative analysis: 1901–1930, 1931–1960, 1961–1990, and 1991–2020. The study employed methods of analysis and synthesis of scientific information, comparative and descriptive analysis, cartographic analysis, and GIS modelling.

At the beginning of the study period, in 1901–1930, most of the lowland territory of Ukraine belonged to climate type D. The most widespread subtype was Dfb, which covered Polissia, most of the Forest-Steppe zone, Sloboda Ukraine, and a substantial part of the Left-Bank region. Climate type C had a much more localised distribution. Subtype Cfa was characteristic primarily of a narrow coastal strip of Crimea. Small areas of dry steppe climate BSk were also recorded in the extreme south-eastern parts of Odesa and Kherson regions (Fig. 1a).

During 1931–1960, the spatial structure of the main climate types remained relatively stable. Type D continued to dominate the central and northern regions of Ukraine, while localised areas of a warmer climate remained in the south (Fig. 1b).

The period 1961–1990 was characterised by relatively cooler conditions. During this period, the smallest extent of subtype Cfa was observed. Central and northern Ukraine largely remained within the Dfb zone (Fig. 1c).

The most pronounced spatial transformations were identified for 1991–2020 (Fig. 1d). One of the main changes was a substantial northward shift of subtype Dfa.

As a result, Dfb retreated from parts of Right-Bank Ukraine, including certain areas of Vinnytsia and Cherkasy regions, while the area occupied by Dfa expanded.

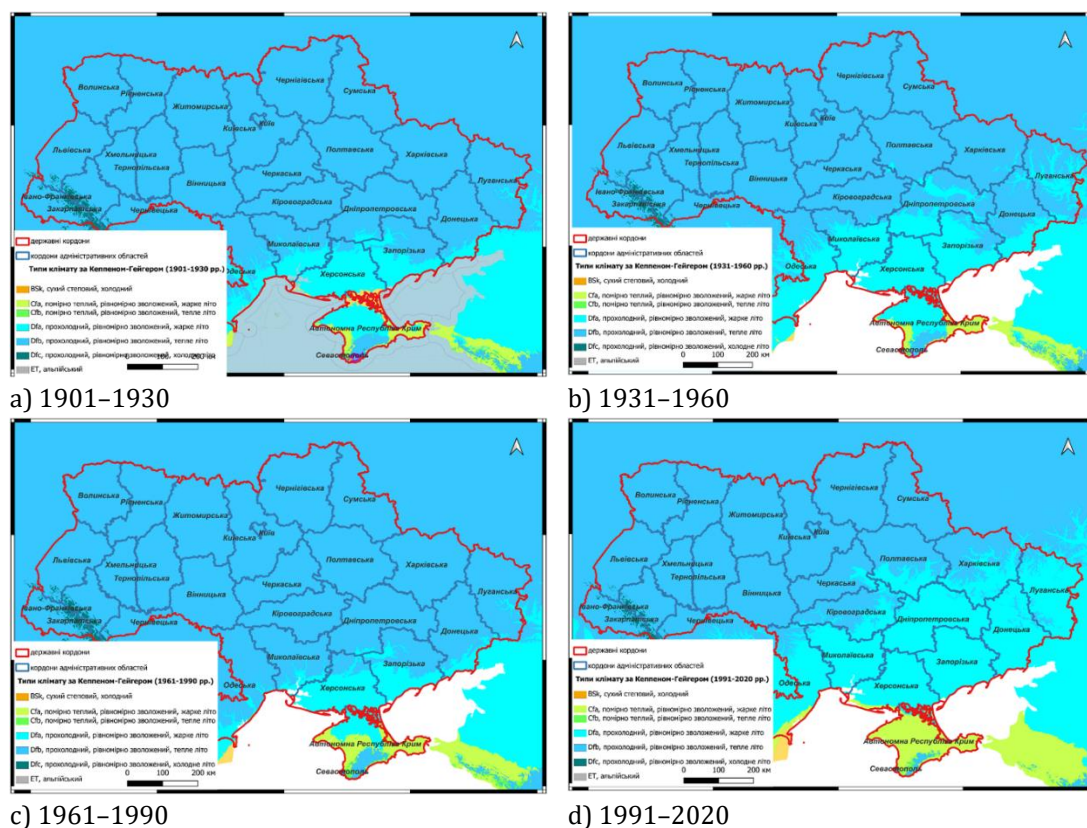


Figure 1 Climate types according to the Köppen–Geiger classification.

Subtype Cfa, a temperate climate with hot summers, also expanded considerably. During 1991–2020, it was recorded not only in the traditional southern areas but also in Odesa and Mykolaiv regions. This indicates a spatial expansion of warmer climatic conditions across the steppe zone of Ukraine.

The Ukrainian Carpathians show particularly pronounced patterns in terms of climate types. Here, climate type D remains dominant due to the altitudinal variation in temperature. At the beginning of the 20th century, subtype Dfc was characteristic of high-elevation areas, particularly those above 1,200 m. During 1991–2020, the boundary of Dfc shifted upwards, while Dfb expanded into parts of the lower elevation belts.

Thus, spatial changes in the climate types of Ukraine have both latitudinal-zonal and altitudinal dimensions. The identified transformations of climate types are important for assessing the future condition of natural and anthropogenic systems. The northward shift of Dfa alters the agroclimatic potential of the Forest-Steppe zone. A longer warm season may create new opportunities for cultivating heat-loving crops, while simultaneously increasing the risks of moisture deficits and drought. The expansion of Cfa in southern Ukraine is associated with hot summer conditions and may require stronger agricultural adaptation measures, particularly the development of more efficient irrigation systems. In urban areas of the south, the development of green infrastructure and the adaptation of urban infrastructure to rising summer temperatures are becoming increasingly important.

Changes in the Ukrainian Carpathians are of particular significance. The contraction of the Dfc area and its gradual replacement by Dfb with increasing elevation indicate a shift in the climatic conditions under which mountain forest ecosystems function. Warming may increase the vulnerability of spruce monocultures and underscore the importance of transitioning towards more resilient mixed-species forest stands. These trends are important not only for Ukraine. The Ukrainian Carpathians form part of the broader Carpathian mountain system; therefore, the identified spatial and altitudinal shifts in climatic conditions should be considered within the wider context of climate and ecological transformations in Central and Eastern Europe.

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Brown trout (*Salmo trutta*) migration through block ramps on the Porębianka Stream: The role of low-flow channels

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KEYWORDS: low-flow channel, block ramp, brown trout, migration, Porębianka stream

This study on the Porębianka stream aimed to assess hydrodynamic conditions in low-flow channels of block ramps and the migration potential of brown trout (*Salmo trutta*). The analysis covered a cascade of 25 block weirs designed to stabilise the riverbed. Field measurements were taken at four different water discharges, ranging from low to high, evaluating parameters critical to fish, such as water depth, flow velocity, and the difference in water levels between the downstream section and the stilling basin. The results showed that the mere presence of a low-flow channel does not guarantee the watercourse's ecological connectivity. At low flow, insufficient depth was the primary obstacle.

In contrast, at higher flow, excessive current velocities and the absence of a safe, slower-flowing corridor acted as barriers. Across the entire cascade, when all hydrodynamic criteria were considered simultaneously, only four low-flow channels - numbered 6, 7, 17, and 19 - were classified as passable or conditionally passable. This analysis indicates that effectively assessing river barriers requires a comprehensive approach that accounts for hydrological variability and continuity along the entire migration route.

Reconstruction of anthropogenic environmental impact in the Tăul Roşia peat bog area, Lăpuş Mountains

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KEYWORDS: wildfire, Tăul Roşia, multi-proxy analysis, erosion, peatlands

Measured by bio indicators, the Carpathian Mountains are some of the richest biogeographical regions in Europe. Many endemic and relict species found in the region are characteristic of high-altitude wetland habitats, such as fens and peat bogs. Peatlands are among the most important paleo-archives for the reconstruction of past environmental changes and disturbance regimes, with the potential to provide the longer-term perspective at a local to regional scale necessary for a sustainable management and restoration of these areas. Anthropogenic activities such as changes in land-use, forest clearance, superimposed on climate change and increasing wildfire risk, represent a key disturbance, threatening the ecological balance of these sensitive landscapes. Long-term information about environmental change in relation to human impact is required for the sustainable management and restoration of higher elevation wetlands. We have reconstructed the impact of anthropogenic activities and wildfire on the environment in the Tăul Roşia peat bog area (Lăpuş Mts, NW Romanian Carpathians). The results show enhanced fire activity in the middle part of the profile, shortly followed by a significant increase in heavy metal concentration and increased soil and bedrock erosion. This might suggest that humans have likely used fire to clear the forests and open access to the pasture and mining sites. This resulted in topsoil removal and the bedrock left exposed to environmental and climatic factors. This study offers insight into the past evolution development of this wetland area and can be used to predict future possible responses of the local environment to anthropogenic stressors.

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Comparative operational analysis of wildfires in Southern France and Romania under increasing climate pressure

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KEYWORDS: wildfires, climate change, civil protection, operational resilience, Romania, Southern France, massive attack, feux tactiques, EFFIS, climate adaptation

Climate change is increasingly influencing wildfire frequency, intensity and operational complexity across Europe, transforming what were once regionally concentrated hazards into continental-scale climate risks. Recent reports from the European Forest Fire Information System (EFFIS) and the Copernicus Emergency Management Service indicate that wildfire seasons are becoming longer, more destructive and geographically more widespread, affecting not only Mediterranean regions but also Central and Eastern European areas previously considered moderately exposed to large vegetation fires.

This paper presents a comparative operational analysis of wildfires encountered during international civil protection missions deployed in Southern France in 2023 and 2024 and vegetation and forest fire interventions conducted in Romania, with particular reference to Bistrița-Năsăud County. The analysis is based on direct operational experience acquired during European wildfire response missions, combined with field observations from Romanian mountainous wildfire interventions and ongoing professional involvement in European projects related to climate adaptation, resilience and disaster risk management.

The study highlights major environmental and operational differences between Mediterranean and Carpathian wildfire conditions. In Southern France, wildfire behaviour is strongly influenced by highly flammable Mediterranean vegetation such as maquis and garrigue ecosystems, characterised by low humidity, volatile organic compounds and extremely rapid fire propagation potential. During operational deployments in the Eastern Pyrenees in 2024, wildfire dynamics were significantly intensified by the Tramontane wind, which accelerated fire spread, increased spotting phenomena and generated rapidly changing fire fronts requiring immediate tactical adaptation.

French wildfire doctrine is largely based on the principle of “massive attack”, consisting of rapid and concentrated mobilisation of ground and aerial resources during the early stages of an incident in order to avoid escalation into large-scale or uncontrollable wildfires. Another major operational characteristic observed during interventions in Southern France is the use of tactical fire techniques (“feux tactiques” or counterfires), implemented by specialised teams to reduce combustible vegetation, redirect fire behaviour and protect exposed communities or strategic infrastructure. In contrast, Romanian wildfire interventions historically evolved within a different environmental context dominated by mountainous coniferous and deciduous forests, more humid ecosystems and difficult accessibility conditions. However, recent climate developments, including prolonged drought periods, rising summer temperatures and increased vegetation dryness, are progressively contributing to more aggressive wildfire behaviour and longer-duration interventions in Romania.

A relevant case analysed in this study is the forest fire intervention in Parva locality, Bistrița-Năsăud County, where operations were complicated by steep terrain, limited access routes, continuous reignition risks and the necessity for aerial support using helicopter water drops.



Figure 1 Wildfire intervention during international civil protection mission in Southern France. Operational observation of Mediterranean wildfire behaviour and collaboration with French personnel specialised in tactical fire techniques ('feux tactiques'). Source: Personal operational archive.



Figure 2 Forest fire intervention in Parva locality, Bistrița-Năsăud County, Romania. The image illustrates mountainous terrain accessibility challenges and dense smoke conditions during suppression operations. Source: Personal operational archive.

The operational characteristics of this intervention demonstrated several similarities with wildfire incidents encountered in Southern France, particularly regarding terrain influence, logistical complexity and the importance of rapid containment strategies under increasingly severe environmental conditions.

The paper argues that climate change is progressively modifying wildfire risk profiles in Eastern Europe, requiring accelerated adaptation of operational doctrines, firefighter training systems and national response capabilities. Participation in international civil protection missions and European climate-related projects offers an important mechanism for institutional learning, operational interoperability and transfer of best practices regarding climate resilience and wildfire management.



Figure 3 Active wildfire front in Parva locality, Romania, showing forest fire propagation in Carpathian vegetation under dry environmental conditions. Source: Personal operational archive.

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The 2025 Broșteni Floods (Romania): Hydrological setting, flood propagation and impacts

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KEYWORDS: climate changes, forest degradation, flash floods, watershed management, water flow, sediment transport

Hydrological risks within forested environments are intensifying under contemporary climate change conditions. Mountainous and submountainous regions, traditionally protected by dense forest cover, are now facing amplified exposure to extreme hydrometeorological hazards. Rising temperatures, increased atmospheric moisture, and the greater frequency of short-duration, high-intensity storms have altered the natural equilibrium of forested watersheds. Forest ecosystems, which act as critical buffers regulating runoff, stabilizing slopes, and enhancing infiltration, are losing their regulatory capacity due to logging, forest degradation, and incomplete regeneration. As a consequence, hydrological responses are becoming more abrupt, contributing to enhanced peak discharge, accelerated surface runoff, and heightened flood potential.

In this context, on July 27, 2025, the Broșteni region (specifically Neagra village extending in the Neagra Broștenilor basin, mainly along the river valley) has undergone an extreme dual-peak rainfall event which delivered approximately 150–180 mm of precipitation within a span of about three hours during its most aggressive second phase, dramatically exceeding the absorption and storage capacity of local soils and forested surfaces.

The affected watersheds—i.e. key sub-basins such as Bradul, Pinul, Bitanul, Jumaț, Om, Obcioara, and Pârâul Arsurilor—exhibited a rapid and highly unstable hydrological response driven by convective storm cells (cumulonimbus and mammatus clouds) producing heavy rain and large hail. The combination of steep terrain, degraded forest vegetation, reduced root cohesion, and heavily saturated soils facilitated the sudden onset of flash floods across multiple river basins. The absence of sufficient forest structure allowed runoff to accelerate downslope, concentrating flow energy and reducing natural retention capacity. As runoff intensified, a series of geomorphological processes became rapidly activated. Sheet erosion, gully formation in deforested catchments, shallow landslides (with scarps as high as 10–12 m, particularly along concave valley slopes), and channel incision yielded substantial volumes of sediments, boulders, and woody debris to the floodwaters. This solid load dramatically increased the destructive power of the floods, transforming them from high-discharge events into complex geomorphological hazards capable of reshaping entire landscapes. The cascading sequence of processes culminated in a catastrophic flood which swept through Neagra village in Broșteni, overwhelming infrastructure and leaving behind considerable destruction.

The floodwaters devastated households, destroyed agricultural lands, and severely damaged road networks, isolating communities and compromising local mobility. Hundreds of residents experienced acute disruptions to their daily lives, with many losing essential resources and facing prolonged recovery periods. More tragically, the catastrophic event affecting the basin of Neagra river claimed the lives of three inhabitants who could not be safely evacuated in time.

Beyond the immediate socioeconomic impact, the geomorphological imprint of the event was profound; the flood reconfigured the morphology of the area by creating extensive alluvial fans at the mouths of tributaries, altering river channels through lateral migration and aggradation, and forming successive flood terraces. Additionally, new gravel ridges and adjustments to stream beds were deposited, indicating the considerable energy and sediment load carried by the streamflow.

This flood event highlights the intricate relationship between forest integrity, watershed stability, and hydrological risk. The Broșteni floods demonstrate that forest degradation not only reduces ecological resilience but also contributes to magnifying the severity of extreme precipitation events. Strengthening forest management practices, restoring degraded forest stands, and implementing integrated watershed strategies are essential steps toward mitigating future flood disasters. Thus, understanding the cumulative effects of land-cover change on hydrological and geomorphological dynamics is critical for safeguarding vulnerable communities and enhancing long-term environmental resilience, serving as a baseline model for analyzing other exposed mountain territories in Suceava County and beyond.

Preliminary environmental study of the site. Functional conversion of an industrial area in the municipality of Botoșani to establish a university centre

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KEYWORDS: environmental assessment, GIS, industrial conversion, university centre, renewable energy, sustainable development

The conversion of an industrial area in the municipality of Botoșani into a university centre requires interventions to be informed by environmental conditions and the risks associated with historical activities. This paper proposes a methodological framework linking environmental assessment and spatial analysis with functional conversion, the energy transition, and sustainable development.

The environmental assessment draws on the preliminary site analysis and research published by Paul-Narcis Vieru on historical heavy fuel oil contamination at Modern Calor. This provides a local reference for identifying contamination sources and migration mechanisms, without extrapolating the findings to the entire site proposed for conversion. The methodology follows the source–pathway–receptor model and includes reconstructing the industrial history, assessing soil, water, and air, and undertaking a preliminary investigation at five indicative sampling locations.

Integrating the data into geographic information systems (GIS) aims to relate potential sources, migration pathways, and receptors to future land uses. The proposed land-use compatibility map will help delineate areas requiring further investigation or remediation and inform the siting of buildings and green spaces.

On this basis, industrial conversion seeks to bring underused sites back into active urban use, make rational use of available land within urban boundaries, and reduce pressure for expansion onto undeveloped land. A university centre is the proposed use for the site. A direct connection to the Cornișa recreational area, integrating the elevated pedestrian bridge and the Pacea hillside into a network of pedestrian routes and green spaces, aims to connect education and research with recreation and the community, in coordination with existing facilities and ongoing projects supported by secured European funding.

The technological transition involves assessing the integration of solar and shallow geothermal energy, the latter harnessed through heat pumps. Solutions will be tailored to energy demand, geological and hydrogeological conditions, and any remediation measures, to prevent subsurface interventions from facilitating contaminant migration.

The approach aligns with quality education (SDG 4), affordable and clean energy (SDG 7), sustainable cities and communities (SDG 11), responsible consumption and production (SDG 12), and climate action (SDG 13). In the absence of site-specific analytical results, the contribution remains methodological and forward-looking, proposing a conversion model grounded in environmental safety, GIS analysis, energy efficiency, and urban integration.

Ecosystem services for climate neutrality in urban geosystems: carbon storage assessment

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KEYWORDS: carbon storage, InVEST, urban geosystems, LULC

1 Introduction

Climate neutrality implies achieving a balance between greenhouse gas emissions and removals. Carbon stored in geosystems does not enter the atmosphere, positively affecting the greenhouse gas balance. This study examines the ecosystem service of carbon storage for three small Ukrainian urban geosystems: Bucha, Vorsel and Irpin. They are located in the physical-geographical region of the Kyiv Polissya, which belongs to Central European mixed forests ecoregion.

2 Methods and Data

The ecosystem service assessment was conducted using Carbon Storage and Sequestration InVEST model, developed by Natural Capital Alliance (Natural Capital Project, 2025). Land Use and Land Cover (LULC) data The data were obtained from city master plans; the classification system was developed by the authors and consisted of three levels: class, type, and species. To receive data on carbon density in aboveground biomass, belowground biomass and mortmass, the density of aboveground biomass was modeled based on data from the Global Ecosystem Dynamics Investigation (GEDI) mission using the methodology described in (Kandii et al., 2026). The biomass density was converted to carbon density using the coefficients given in (IPCC, 2006), the ratio of aboveground biomass, belowground biomass, and mortmass is taken from (Vasylyshyn et al., 2021). The soil carbon density was obtained from OpenLandMap-soildb (Hengl et al., 2026). For the monetary assessment, a social cost of carbon of 39 USD per metric ton was used, as proposed in (Ashenfarb and Kotchen, 2025).

3 Results

The total amount of carbon stored by the Bucha urban geosystem was estimated at 584,100.13 metric tons, which is equivalent to 22,779,905 USD; for Vorsel, the figure was 220,615.79 metric tons (8,604,046 USD), and for Irpin, the carbon storage volume amounted to 930,044.32 metric tons (36,271,728.48 USD). The data obtained depends directly on the area of the urban geosystem; therefore, it is more appropriate to use relative indicators when comparing the urban geosystems under study. Thus, the relative volumes of carbon storage in Bucha are the lowest, amounting to 221.89 metric tons/hectare and 8,654 USD/hectare; while Vorsel has the highest values—265.96 t/ha and 10,372 USD/ha, and Irpin has 250.84 t/ha and 9,783 USD/ha. These differences may be due to variations in the density of stored carbon for a given LULC species across different urban geosystems, as well as the structure of LULC in terms of both the species of LULC and their respective areas.

To determine the reasons for the observed distribution of relative carbon storage volumes, it is necessary to identify the LULC species that have the greatest impact on the average relative value, which can be done by assessing the contribution of each component to the average

deviation. However, this method is not suitable for estimating the contribution of LULC species with zero carbon storage density. To investigate the impact of the area of such sites on the weighted average, the percentage of these sites' area relative to the total area of the urban geosystem was calculated.

The following patterns were identified: Vorzel ranks first due to the highest carbon storage density values in the vast majority of LULC species, a high contribution to the weighted average from LULC species with high stored carbon density (health and recreation facilities, green areas with mixed vegetation), and the smallest percentage of area for LULC species with zero stored carbon density. Irpin ranks in the middle due to the presence of both positive factors (the contribution of the LULC species with the highest stored carbon density is the largest) and negative factors (the lowest stored carbon density values in the vast majority of LULC species, the largest proportion of area occupied by LULC species with zero carbon stock density). The contribution of natural coniferous vegetation resulted in a higher average value compared to Bucha; however, the low carbon stock density values for the remaining species keep the average below the corresponding value for Vorzel. In terms of carbon storage density across LULC species, Bucha could rank second. However, unlike in Irpin, the contribution of species with the highest carbon storage density is small here. Furthermore, Bucha is characterized by the largest contribution – among the studied urban geosystems – to the weighted average value of transportation lands, where the density of deposited carbon is very low.

The highest relative carbon storage density for all urban geosystems is observed in natural coniferous vegetation: 365.71 t/ha for Irpin, 335.79 t/ha for Vorzel, and 320.61 t/ha for Bucha. The distribution of relative volumes of carbon storage ecosystem services by LULC class is the same across the three urban geosystems studied. In descending order of carbon storage density, the LULC classes form the following sequence: green infrastructure – reserve lands – built-up areas – transportation lands – blue infrastructure and other lands (no carbon stored).

4 Conclusions

Using the InVEST Carbon Storage and Sequestration model, it is possible to estimate the total carbon storage by urban geosystems. An analysis of the relative volumes of carbon storage ecosystem services provided by LULC units helps to understand the reasons for differences in these volumes across different urban geosystems, as well as to identify the LULC units that are most conducive to the provision of this ecosystem service.

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Geochemical variability within archaeological ceramic fragments and its implications for raw material provenance studies

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Ceramic fragments represent one of the most common categories of archaeological material and constitute an important source of information on the raw materials used, production technologies, and the circulation of objects in the past. In the Moldova region (Romania), the abundance of archaeological sites provides an opportunity to investigate the technological and compositional characteristics of ceramics and to assess the relationship between local production and the sources of raw materials available in the region. In this context, the Fetești – La Schit archaeological site (northern Moldova) represents an interesting case for the investigation of ceramic material using archaeometric methods, as compositional analysis may contribute to understanding the origin of raw materials and the particularities of the production process.

The present study evaluates the intra-fragment geochemical variability of archaeological ceramics from the Fetești – La Schit archaeological site, in the context of using geochemical composition of ceramics to determine the provenance of the raw material. Ten ceramic fragments belonging to different chronological periods, together with 15 samples of in situ clay, local soil and sediments were analysed using X-ray fluorescence spectrometry (XRF). For each ceramic fragment, three distinct areas were measured: the inner surface, the central part, and the outer surface. This sampling strategy aimed to assess compositional variability within individual fragments and to identify the potential influence of use, alteration, and post-depositional processes on the initial geochemical signature of the ceramic paste. The obtained data were subsequently evaluated using Principal Component Analysis (PCA).

The results reveal significant compositional differences between the three areas analysed within individual ceramic fragments. The inner and outer surfaces exhibit greater variability, which may be associated with both use-related processes and post-depositional alterations. In contrast, the central part of the fragments shows a more compact distribution in the multivariate space and a stronger alignment with the group of analysed local raw materials. This behaviour suggests that the central part of the ceramic fragments preserves, to a greater extent, the geochemical signature associated with the original raw material and is less affected by secondary processes that may alter the composition of the fragment surfaces.

The PCA results therefore support the importance of sampling position in the interpretation of provenance analyses. Although the alignment between the central subsamples and the local raw materials does not allow all fragments to be conclusively attributed to a local source, it indicates that the ceramic core represents the most appropriate area for assessing provenance relationships based on elemental geochemical composition. In this regard, the exclusive analysis of the inner or outer surfaces may lead to results that do not fully reflect the original composition of the ceramic material. These results support the removal of superficial layers, where the state of preservation of the material permits, and the analysis of the central part of the fragment. Such an approach allows a better distinction between the geochemical signature

associated with the natural resource used and modifications resulting from the interaction of the ceramic material with the environment.

A distinct case is represented by ceramic fragments containing pigmented areas. These areas exhibit a chemical composition different from that of the ceramic core, characterized by elevated iron concentrations, potentially associated with the use of mineral pigments, as well as local enrichments in lead and arsenic. These characteristics may reflect particular aspects of ceramic preparation and decoration technology; however, possible post-depositional contamination cannot be excluded. Therefore, the geochemical concentrations associated with pigmented areas should be interpreted with caution and cannot be directly used as indicators of the provenance of the ceramic paste. Mineralogical and petrographic investigations are required to distinguish between the original composition of the decoration and secondary modifications.

Overall, the results highlight the importance of assessing the within-fragment geochemical variability in archaeometric provenance studies of archaeological ceramics and demonstrate that sampling strategy can significantly influence the interpretation of geochemical relationships. The central part of the analysed fragments proves the most coherent signal for characterizing ceramic composition and comparing it with potential raw material sources. The integration of XRF analyses with multivariate statistical methods such as PCA, together with mineralogical and petrographic investigations, provides a more robust approach for distinguishing the primary geochemical signal from secondary modifications and for assessing the relationships between raw materials, production technology, and the provenance of ceramics from archaeological sites. In this respect, the present study may contribute to integrating archaeological ceramic geochemistry into the analysis of long-term interactions between human communities and the natural resources of the environment in northern Moldavia.

Tracing climate change: Contribution towards improved climate change education and research

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KEYWORDS: climate change education, geomorphology, environmental vulnerability, field-based learning, Erasmus+

The increasing impacts of climate change on natural environments require innovative educational approaches that integrate scientific research, field-based learning, and digital technologies. The Erasmus+ project Tracing Climate Change (TRACE) was designed to address this challenge by enhancing climate change education through an interdisciplinary geomorphological framework and international academic cooperation.

Implemented by the University of Bucharest, the National and Kapodistrian University of Athens, Aix-Marseille University, and E3STEM, the project investigated geomorphological evidence of climate change across a variety of environments, including deltaic, coastal, and mountain systems. Field research conducted in Romania, Greece, and France examined key indicators of environmental change, including sea-level fluctuations, shoreline dynamics, neotectonic activity, and permafrost degradation, using modern geospatial, geophysical, and laboratory-based methodologies. The scientific outcomes were translated into open-access educational resources, including lecture materials, video lessons, interactive maps, virtual field trips, and online workshops.

This presentation discusses the TRACE project's conceptual framework, research activities, educational outputs, and dissemination strategy. It highlights the project's contribution to bridging research and education, promoting experiential learning, and supporting the development of climate literacy among higher education students.

Phytoliths as proxies for past vegetation and environmental conditions in high-altitude regions

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Reconstructing past vegetation in high-altitude regions is important for understanding the environmental conditions associated with prehistoric human occupation. Phytolith analysis can provide information on past plant communities, particularly in archaeological contexts where other botanical remains are scarce or poorly preserved.

This study presents phytolith data from Istyyskaya Cave, located at 4,060 m a.s.l. in the Eastern Pamir, Tajikistan. The archaeological sequence includes levels dating from the Epipalaeolithic–Neolithic to the Bronze Age and Medieval period. Phytolith assemblages from successive stratigraphic levels were analysed to examine the composition of herbaceous plant remains and their variation through time.

The phytolith assemblages are dominated by grass-derived forms (Poaceae), suggesting an important contribution from Pooideae. Differences in assemblage composition between stratigraphic levels indicate variations in grass-derived plant inputs through time. These variations may reflect changes in the availability of herbaceous plants or differences in the plant material introduced into the cave during successive periods of human occupation. The nature of the cave and its deposits, together with the presence of an archaeologically sterile layer (Layer 4), suggests that the occupation deposits are predominantly anthropogenic in origin. This context highlights the need to distinguish between changes in the surrounding vegetation and plant inputs associated with human activities.

From this perspective, the development of modern reference datasets based on present-day vegetation and off-site sedimentary deposits could help assess potential differences between archaeological and natural phytolith assemblages, contributing to a better interpretation of vegetation signals and human-related plant inputs in high-altitude environments.

Acknowledgement

This work was supported by the French government through the France 2030 investment plan managed by the National Research Agency (ANR), as part of the Initiative of Excellence Université Côte d'Azur under reference number ANR-15-IDEX-01.

Herbaceous species with high conservative value outside protected steppe areas in Suceava county (Romania)

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KEYWORDS: biodiversity, habitats, threats, collaboration

Floristic surveys conducted outside natural reserves between 2024 and 2026 revealed high-value ecological habitats in the steppe and forest-steppe zone of Suceava county. These areas feature well-preserved plant communities and rare flora within species-rich grassland remnants. Among the studied sites, Dealul Teișoara stands out for its exceptional plant diversity and good conservation status, serving as a key regional biodiversity hub. The preservation of these ecosystems relies heavily on traditional meadow management, which has helped maintain their ecological balance and plant structure.

However, the research also identified natural and human pressures threatening habitat integrity and sensitive plant populations. Key threats include land conversion to agriculture, premature mowing, overgrazing or, conversely, land abandonment, scrub encroachment, the spread of competitive species, altered hydrology, and climate fluctuations. Intensive fertilization, pesticide use, drainage, and other activities further fragment and degrade these habitats.

These findings suggest that expanding protected areas near sites like Calafindești merits consideration. Nevertheless, effective conservation currently depends primarily on working directly with landowners and local authorities. A strong example is the "La Toloacă" site in Stroiești, where owners voluntarily agreed to measures protecting *Fritillaria meleagris* and *Trollius europaeus*. This approach demonstrates that biodiversity can be effectively protected through local partnerships and shared responsibility.

We hope these results serve as a foundation for future interdisciplinary research and collaborative conservation efforts involving scientists, local authorities, landowners, and communities to ensure the long-term protection of biodiversity outside protected areas.

Assessment of the efficiency of hydraulic barriers and the kinetics of leachate stabilization in non-compliant urban landfills: A comparative study of the Săveni and Darabani sites, Romania

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KEYWORDS: biogeochemical stability, Monitored Natural Attenuation (MNA), biodegradability ratio, bentonite geocomposite (GCL), shallow groundwater aquifer, Natura 2000 Network

This study investigates, from a biogeochemical and ecotoxicological perspective, the behaviour of non-compliant urban waste landfills (class “b”) in Botoșani County during the post-closure stage, comparatively analysing two strategies for reducing ecological risk: engineered impermeable isolation using composite geosynthetic systems and monitored natural attenuation (MNA), supported by the native lithological matrix. By correlating lithostratigraphic profiles, kinetic models of biodegradable organic carbon degradation, and the physicochemical parameters of interstitial fluids, the research confirms the completion of active methanogenic phases at the Darabani site (residual COD-Cr values of and a biodegradability ratio of), demonstrating the transition of the waste body toward the “biologically stabilized landfill” stage (biologically extinguished). In parallel, the Săveni site demonstrates the effectiveness of an anthropogenic intervention involving centripetal geometric reshaping, associated with a reduction of more than 70% in the initial contamination footprint and sealing with a bentonitic geocomposite (GCL). The study provides the scientific basis required to assess the vulnerability of the regional shallow groundwater aquifer of the Moldavian Plain (ROPR07) and the adjacent bird protection area (ROSPA0049), constituting rigorous empirical support for the preparation of specialized documentation in European environmental litigation (Case C-389/26).

Assessment of the long-term dynamics of non-compliant municipal landfills requires moving beyond an engineering approach focused exclusively on the physical isolation of the residual mass, and instead treating these sites as major biogeochemical discontinuities introduced into the geosphere. During the post-closure stage, the heterogeneous waste mass remains an open biochemical reactor interacting with the lithosphere, hydrosphere, and atmosphere through coupled processes of hydraulic percolation, ionic solubilization, and anaerobic diagenesis of the organic fraction.

At the level of Botoșani County (, resident population of inhabitants, with a rural population share of), the transition toward integrated waste management required the successive closure of class “b” urban landfills (Dorohoi in 2008, Botoșani in 2012, Darabani in 2014, and Săveni in 2016) and the concentration of waste flows at the compliant Stăuceni Integrated Municipal Waste Management Centre (CMID). This reconfiguration initiated the critical stage of monitoring residual processes in historical closed landfills.

The main hydrogeological vulnerability pathway is leachate generation. If uncontrolled, this effluent, characterized by a high organic and mineral load, may percolate vertically into the permeable shallow groundwater aquifer of the Moldavian Plain (water body code ROPR07) or

migrate laterally by diffusion toward the surface-water drainage network. The Săveni landfill is particularly relevant due to its proximity to the Valea Boului stream (a tributary of the Bașeu River) and its location only from the ROSPA0049 special bird protection area, "Iazurile de pe valea Ibăneșei – Bașeului – Podrigăi".

The study comparatively examines two distinct paradigms for ecological risk stabilization, evaluated on the basis of field and laboratory data obtained in July 2026:

1. Advanced engineered isolation paradigm (Săveni): characterized by relocating the waste mass within the boundaries of public property, centripetal morphological reshaping, and structural sealing using low-permeability synthetic bentonite barriers (GCL).
2. Monitored natural attenuation paradigm (Darabani): based on the kinetic depletion of the biodegradable substrate and the natural adsorption, cation-exchange, and hydraulic-retention properties of the local pelitic horizons, without the addition of synthetic materials.

Analytical quantification of these mechanisms provides the factual support necessary to clarify environmental compliance before the European Union courts, particularly in the context of the infringement proceedings that are the subject of Case C-389/26.

Morpho-touristic landscapes and geodiversity analysis of the Bran – Rucăr – Dragoslavele Corridor (Romanian Carpathians)

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KEYWORDS: Bran – Rucăr – Dragoslavele Corridor, morpho-touristic landscape, geotourism, Romanian Carpathians, geomorphosite, geodiversity analysis

This study makes contributions to the quantitative assessment of the geotourism potential of the Bran-Dragoslavele Corridor (in the Southern Romanian Carpathians) through the calculation of the geodiversity index. The main aim of the research is to identify and systematise the types of morpho-touristic landscapes, as well as to map the aforementioned index. The resulting raster map can be printed in two versions: one containing geological vector data (paleontological sites featuring Mesozoic invertebrates from the Tethys Ocean and a bio-geological nature reserve) and the other containing geomorphological vector data (proposed geomorphological sites and other tourist attractions of geomorphological significance). In the study area, the varied geological substrate and the diversity of landform types arising from it have led to the emergence of a similar range of landscapes with tourist potential, resulting both from the combination of constituent elements of distinct landform types (karstic landforms combined with those formed on conglomerates, sandstones or crystalline rocks), and through the combination of forms belonging to the same type of landform (those developed on limestone). Morpho-touristic macro-landscapes include the basic landscapes that endow the mountain sub-unit under analysis with remarkable geotouristic potential, owing to the spatio-temporal evolution of the relief (determined by lithology, tectonics and climatic conditions), as well as the presence of numerous fossil-bearing deposits which may shed light on the ecological aspects of the palaeogeographical environments. The final versions of the map will be useful not only to visiting tourists and researchers, and tourism service providers, but above all to local authorities, who have a stake in making decisions regarding the promotion of geotourism, given the existence within the geographical territory of the Transcarpathian corridor under study of numerous geological and geomorphological tourist resources that have been insufficiently promoted and utilised.

Hydro-geomorphological connectivity, flood exposure and climate-sensitive settlement vulnerability in the Moldavian Plateau, Eastern Romania

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KEYWORDS: settlement vulnerability, hydro-geomorphological connectivity, flood exposure, geomorphological hazards, De Martonne index, climate change

1 Introduction

Environmental risk at settlement scale cannot be interpreted solely within the built-up boundary, because geomorphological processes may develop on surrounding slopes while remaining topographically connected to inhabited areas, whereas flood hazard is concentrated along valley corridors and may directly intersect buildings, transport infrastructure and public facilities. The research synthesises two published stages and the current development of an ongoing doctoral project focused on settlement vulnerability in the Moldavian Plateau. The methodological framework combines: (i) a terrain-controlled Hydro-Geomorphological Contribution Area delineated for each built-up area according to interfluvies, local elevation highs, slope orientation, drainage pathways and local base level; (ii) a separate upstream contributory watershed used as spatial context for relief and drainage; (iii) available flood-hazard polygons corresponding to a 1% annual exceedance probability under present conditions and, where available, the climate-adjusted scenario; and (iv) exposed elements including buildings, households, infrastructure and facilities. The current geomorphological analysis comprises 1,957 built-up areas. Flood exposure is evaluated through GIS intersection, while potentially exposed population is estimated from household counts using an average occupancy of 2.6 persons per household, supplemented by building-typology rules for apartment blocks. The approach is conceived as a regional screening framework and does not replace detailed geotechnical, hydrological or hydraulic modelling.

2 Results

The updated geomorphological inventory within the 1,957 Hydro-Geomorphological Contribution Areas contains 7,948 landslide polygons, 8,819 gullies and 2,530 mapped rill-erosion surfaces. Landslides occur in 1,508 analytical areas (77.1%), gullies in 1,398 (71.4%) and rill erosion in 1,151 (58.8%). Because process categories overlap, the same area may contain several process types; their presence is interpreted as potential influence on the settlement rather than independently verified direct impact. Published flood-exposure results indicate approximately 68,750 potentially exposed inhabitants in Iași, 36,756 in Bacău and 2,550 in Vaslui under the 1% annual exceedance probability scenario. At basin scale, the Siret category includes 12,948 potentially exposed inhabitants, 4,993 households and 282 facilities, while the aggregated Prut-related category includes approximately 4,000 inhabitants, 1,573 households and 206 facilities, and the Bârlad category 4,538 inhabitants, 1,405 households and 62 facilities. These results quantify exposure, not direct economic loss or structural damage.

3 Climate-oriented development

The next stage will integrate mean annual temperature and precipitation data for a reference period and projected periods to 2100. Climatic aridity will be summarised using the annual De Martonne index, $I = P/(T + 10)$, enabling comparison of present and projected hydro-climatic conditions at settlement or administrative-unit level. These climate indicators will remain analytically distinct from the geomorphological and flood components and will be used to strengthen the interpretation of long-term changes in settlement vulnerability and adaptation priorities.

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Interdisciplinary research in archaeological sites of the Suceava Plateau. Preliminary considerations upon soil evolution in Bronze Age burial mounds

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Starting over 5500 years ago, for a period of nearly 2,000 years, the Precarpathian forest-steppe area was inhabited by communities belonging to three populations: the Jamnaja Culture (3200-2800 BC), the Corded Ware Culture (2700-2300 BC) and the Trzciniec Cultural Circle (1800-1300 BC, its southeastern version – the Komarów culture). These communities successively established barrow cemeteries, creating a distinctive funerary landscape, in three “waves of kurganization”. Through the way of arrangement, these three tumulus traditions can, at a theoretical level, be captured in a single microregion, the Suceava Plateau, along an area located in the interfluvies between the Siret and Suceava rivers, with several tributaries. In this microregion, radiocarbon dates, details of funerary rituals and archaeological materials indicate that human habitation was intense starting from the turn of the 4th and 3rd millennia BC.

The tradition of excavating barrow cemeteries in the discussed area dates back to the 19th century, when barrow sites were investigated by Austrian archaeologists (Szombathy, 1895). Research of the barrow population in this territory was continued by Romanian scientists gathered around the National Museum of Bukovina and the “Ștefan cel Mare” University of Suceava. Thanks to a recent project of the National Science Center of Poland (2023/49/B/HS3/00966), the investigation of the Suceava Plateau regarding the remains dating back to the Bronze Age enters a new stage, comprising extensive interdisciplinary studies carried out by a Polish-Romanian team. The project aims at a complex, multidisciplinary investigation of several funerary monuments (tumuli), both from an archaeological, geomorphological, geological, pedological point of view, in addition to those already researched and published, from Adâncata, Horodnic de Jos and from other barrow cemeteries in the mentioned area. Field research started in the fall of 2024 and will continue, according to the project program, until the summer of 2027.

In this campaign we will try to answer a series of questions regarding the origin of the appearance of barrow cemeteries in the three separate time intervals, the religious aspects and social differentiation of specific populations, as well as their interactions with neighbouring communities at a macro-regional scale. On the other hand, the impact of human communities on the environment at a micro-zonal scale is taken into account, as well as a series of correlations between archaeological information and pedological data, in order to highlight how soils evolve. To answer these questions, a working methodology was developed, which includes a wide range of methods: LIDAR scanning, magnetometry and GPR surveys, preliminary *core drilling*, actual archaeological excavations, soil observations and analyses. The samples of organic material obtained were dated using the radiocarbon method (AMS). After the field research, several dozen samples (bone, charcoal) will be selected from various archaeological complexes, which will then be subjected to detailed analyses.

The soil samples resulting from the drillings were analysed pedologically, following several morphological aspects and typological and taxonomic classification. During the excavations, we took samples for a detailed description and laboratory analyses. The soil morphology helps to establish the contact between the tumulus substrate, the archaeological material and the cover and to understand the pedogenetic evolution of the soils in the barrows, in relation to their morphometric characteristics and construction method. In the larger burial mounds, distinct pedogenetic sequences can be distinguished: a fossil soil is found in the mound's substrate and a new soil has developed above in the mantle. Also, we will examine how certain chemical elements are distributed across soil horizons.

Long-Term Channel Adjustments of the Negru River: A Historical and Morphometric Analysis

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River channel morphology is continuously shaped by the interaction between natural fluvial processes and anthropogenic pressures. Understanding long-term channel adjustments provides valuable information on the evolution of river systems and their response to environmental changes. This study investigates the historical dynamics of the Negru River, located within the Eastern Carpathians, in the eastern sector of the Brașov Depression, more specifically within the Târgu Secuiesc Depression. This depression forms a distinct embayment-like landscape drained by the hydrographic network of the Negru River.

The historical evolution of the Negru River channel was investigated using a multi-temporal cartographic and remote-sensing dataset covering approximately 158 years. The analysis incorporated materials from the Second and Third Military Topographic Surveys, with reference years of 1860 and 1890, the 1977 topographic map, and satellite imagery acquired in 2018. These sources were used to extract and compare several morphometric parameters, including the longitudinal profile, sinuosity index, bankfull channel width, meander radius of curvature, and bank depth.

The results reveal substantial morphological adjustments of the Negru River channel throughout the analysed period. One of the most significant changes is the reduction in channel length by approximately 19.5 km, corresponding to an average rate of about 160 m per year. The river has also experienced a marked reduction of index sinuosity and meander curvature, indicating significant planform adjustment. In addition, the minor channel has progressively narrowed, while increased bank depth suggests enhanced lateral and vertical erosion in certain channel sections.

The observed changes are primarily associated with anthropogenic intervention, which has considerably modified the natural dynamics of the river channel. Nevertheless, climatic variability and tectonic controls also contribute to the functioning and morphological development of the fluvial system. Climatic conditions influence river discharge through the occurrence of floods and prolonged drought periods, thereby affecting sediment transport, erosion, and channel adjustment. Tectonic characteristics, although less influential in the recent evolution of the channel, contribute to the broader geomorphological framework and partly control the spatial configuration and typology of the river channel.

Overall, the results provide a comprehensive perspective on the long-term morphological evolution of the Negru River and highlight the complex relationship between natural processes and human-induced changes. The findings place the evolution of the Negru River within the broader context of Central and Eastern European fluvial systems and contribute to a better understanding of the interaction between river dynamics, environmental variability, and anthropogenic intervention.

Subfossil chironomid-inferred mean July air temperature from Lake Bezbog, Pirin Mountains (Bulgaria): progress of an ongoing reconstruction

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KEYWORDS: subfossil chironomids, temperature reconstruction, Holocene, Southeastern Europe, Balkan Mountains

Southeastern Europe, and particularly the high-altitude regions of the Balkan Mountains, remains underrepresented in chironomid-based quantitative palaeotemperature reconstructions, despite the well-established sensitivity of chironomid assemblages to summer temperature change. This contribution presents the design and current progress of a chironomid-inferred mean July air temperature reconstruction from glacial Lake Bezbog (2,239 m a.s.l., Pirin Mountains, Bulgaria), undertaken as part of an ongoing PhD project. A ~8 m sediment core recovered from Lake Bezbog was sampled at 7 cm resolution for subfossil Chironomidae analysis. The resulting assemblage is diverse, comprising over 35 taxa dominated by cold-stenothermic, profundal morphotypes typical of high-altitude oligotrophic lakes alongside the more sporadic occurrence of taxa more commonly associated with warmer or more productive conditions. Preliminary lithostratigraphic evidence indicates a continuous lacustrine sequence suitable for high-resolution, multi-millennial temperature reconstruction. Once complete, the resulting record will provide the first quantitative estimate of Holocene summer temperature variability from the Pirin Mountains and will be compared with existing reconstructions from the Carpathians, the Mediterranean and other European mountain regions to evaluate the spatial coherence of Holocene climate variability across southern and eastern Europe. The Bezbog record forms part of a broader multi-proxy study of this high-altitude Balkan catchment. By extending chironomid-based temperature reconstruction to an underrepresented sector of the Balkan Mountains, this work contributes to strengthening regional coverage within European palaeoclimate networks and data-model comparisons.

Assessing the preservation of paleoclimate proxy carbonates using FTIR spectroscopy

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KEYWORDS: carbonate temperature proxy, FTIR

1 Introduction

The reliability of carbonate paleoclimate proxies depends on distinguishing preserved mineral characteristics from changes caused by transformation. Our is especially relevant to the metastable ACC–ikaite–calcite system, where dehydration and crystallization may modify both mineral structure and geochemical signals. This contribution examines how FTIR spectra of carbonate mixtures can provide complementary information on phase composition, hydration, and structural order, and considers how these observations could be used for estimating the degree of alteration and to the assessment of carbonate suitability for paleoclimate reconstruction.

2 Climate significance and transformation of carbonate archives

Carbonate minerals preserve information on environmental conditions during precipitation and subsequent alteration. Ikaite ($\text{CaCO}_3 \cdot 6\text{H}_2\text{O}$) is particularly relevant because its natural occurrence is commonly associated with cold environments. Calcite pseudomorphs after ikaite, known as glendonites, are consequently used in paleoclimate reconstruction. However, neither the presence of a pseudomorph nor its geochemical composition can be interpreted independently of its transformation history. Establishing whether the original mineralogical and geochemical information has been preserved requires an assessment of the phases present, their hydration and structural state, and the processes that produced the observed assemblage. Amorphous calcium carbonate (ACC), ikaite, and calcite represent structurally different materials within this system. ACC lacks long-range crystalline order and can act as a precursor or an intermediate in carbonate transformation. Ikaite contains abundant structural water, whereas calcite is an anhydrous crystalline carbonate. Their coexistence can therefore provide information about incomplete transformation, dehydration, and crystallization. Nevertheless, an observed phase assemblage does not uniquely establish a transformation pathway: similar mixtures may arise under different environmental conditions and through different histories of precipitation and alteration.

Experimental work by Lázár et al. (2023) demonstrated that ACC materials formed as precursors and through ikaite dehydration can differ in morphology, water content, and stability. More recent experiments showed that ikaite transforms to stable carbonates, predominantly calcite, through a nanosized ACC intermediate in both solution and air (Lázár et al., 2025). Transformation in aqueous environments was accompanied by substantial changes in oxygen isotopic composition. Calcite–water oxygen isotopic equilibrium was approached within approximately one week at 8 °C and one day at 15 °C under the experimental conditions. These results emphasize that mineral transformation can affect a carbonate archive on timescales that are very short relative to geological deposition.

The present extended abstract develops the approach investigated in the ongoing study by Karlik, Lázár, and Németh, *Qualitative and Quantitative Analysis of ACC, Ikaite, and Calcite Phases in Binary and Ternary Systems Using FTIR Spectroscopy*. Its central premise is that mixed carbonate spectra contain useful information beyond the identification of individual phases. Combined interpretation of carbonate and water-related absorption features may support estimates of phase proportions and provide indicators of hydration, structural order, and crystallinity. These complementary observations could help assess the preservation and extent of alteration of natural climate-indicating carbonates.

3 Experimental approach and findings of the ongoing study

The ongoing study uses laboratory-prepared carbonate mixtures of known mass composition to investigate relationships between FTIR spectral features and the proportions of ACC, ikaite, and calcite. Calcite was obtained as an analytical-grade material and checked using X-ray diffraction (XRD). ACC and ikaite were synthesized under cold conditions. Rapid filtration after mixing the carbonate and calcium solutions was used to prepare ACC, while a longer reaction period of approximately 20–25 minutes at 0–4 °C allowed ikaite to form. The starting materials were examined using XRD and scanning electron microscopy (SEM) to support phase identification and assess their morphology.

Four ternary mixtures were prepared, with nominal component fractions close to 25:25:50, 24:51:24, 50:25:25, and equal thirds for ikaite, calcite, and ACC, respectively. Mixing was performed carefully in an agate mortar while avoiding grinding, and measurements began immediately to limit changes in the metastable components. ATR-FTIR spectra were recorded using a Bruker Vertex 70 spectrometer with a diamond ATR accessory. Each spectrum comprised 64 scans over 4000–400 cm^{-1} at 4 cm^{-1} resolution, and each mixture was measured three times. These precautions are relevant because sample handling and measurement conditions can change the material being characterized.

The spectral evaluation considered both band heights and integrated band areas, rather than restricting the analysis to a single phase-specific marker. Selected carbonate and water-related features were expressed as pairwise ratios, and approximately 300 candidate expressions were screened against the known component proportions. In the current manuscript, 29 candidate ratios for calcite and 38 for ikaite are reported above a threshold labelled $R^2 > 0.90$. Four candidate ratios for ACC fall within a lower reported R^2 range of approximately 0.80–0.85. These findings indicate different levels of sensitivity to the components within the investigated mixtures, with less distinct quantitative relationships for ACC.

The carbonate ν_3 absorption region, including features near 1472 and 1395 cm^{-1} , is relevant to ACC-containing mixtures. However, these features overlap with contributions from other carbonate phases, and the 1395 cm^{-1} band cannot be treated as a unique ACC marker. Its position and shape may instead reflect local coordination and short-range structural order. Water-related bands also contribute useful information because ikaite and ACC contain water in different environments. Their ratios reflect changes in the combined spectrum, although they do not independently isolate the water content of each phase. The resulting expressions should therefore be regarded as preliminary calibration candidates. The four mixture compositions and repeated measurements support initial screening, while independent mixtures are needed to establish predictive accuracy and separate composition effects from changes in hydration or structure.

4 Information content and application to natural carbonates

The value of FTIR analysis lies in interpreting several spectral properties together. Phase-sensitive carbonate features can support identification and compositional estimates, while changes in band width, splitting, and relative intensity can indicate differences in structural

order between amorphous and crystalline components. Water-related stretching and bending features provide information on hydration and water-binding environments. In a transforming mixture, these observations can be considered jointly to assess whether changes are consistent with loss of hydrated material, formation of an amorphous intermediate, or increasing contributions from crystalline carbonate. Such interpretation requires suitable reference materials because phase proportions, hydration, and crystallinity may all influence the same spectral region.

Water-band intensities should not be equated directly with absolute water content without calibration. Structural water, adsorbed moisture, and water associated with other minerals may contribute to natural sample spectra. Similarly, a change in carbonate-band shape is an indicator of structural state rather than a direct quantitative measure of crystallinity unless it has been independently validated. XRD, thermal analysis, and microscopy can provide complementary evidence where quantitative interpretation is required. An amorphous contribution can be quantified by appropriate XRD procedures using standards; the difficulty addressed here is its determination from the diffraction data and sample conditions used in the ongoing study.

For natural climate-indicating carbonates, the proposed approach could help estimate the degree of transformation and assess the preservation of the mineral assemblage before geochemical interpretation. The isotope experiments of Lázár et al. (2025) provide a reason for this assessment: aqueous transformation can promote oxygen isotope exchange, so a glendonite may record early diagenetic alterations rather than retain an unchanged ikaite signature. FTIR does not measure that exchange directly, and a spectrum alone cannot establish whether an isotope signal is primary. It can nevertheless identify mineralogical characteristics that warrant closer examination. Application to natural samples must also account for other carbonate polymorphs, silicates, organic matter, and variable ATR contact. The ongoing calibration study thus provides an experimental basis for extracting complementary information from ACC-ikaite-calcite spectra. With independent validation and reference materials representative of natural samples, FTIR could contribute to estimates of alteration and to the assessment of carbonate suitability for paleoclimate reconstruction. The intended outcome is a more informed evaluation of phase composition, hydration, and structural preservation.

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Lake sediment evidence and historical records of climate and landscape change in the Eastern Carpathians

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KEYWORDS: lake sediments, historical climatology

1 Introduction

Mountain lake sediments record the combined effects of climate, catchment vegetation, erosion and human land use. Historical documents provide a complementary archive of weather extremes and their social consequences, although their spatial coverage and temporal resolution differ from those of sediment records. We compare multiproxy results from Lake Bolătău-Feredeu in Bukovina, Romania, with published historical and archaeological evidence from the Carpathian region. The comparison addresses the Roman Warm Period, the Little Ice Age, and evaluates whether changes in the lake-catchment system are consistent with regional climatic conditions or better explained by local landscape disturbance.

The Roman Warm Period is used here as a broad chronological framework rather than a uniform climatic state across Europe. The preliminary Roman-period dataset focuses on approximately 480 BCE–267 CE, with the interval around 50 BCE–200 CE highlighted in the presentation. Historical reconstructions show substantial regional and seasonal variability during this interval (Stangl and Foelsche, 2022).

2 Study area and analytical approach

Lake Bolătău-Feredeu lies at 1,134 m above sea level in the Eastern Romanian Carpathians. The small, landslide-dammed lake has an area of approximately 0.3 ha, a catchment of approximately 30–31 ha and a measured maximum depth of about 5.2 m. Its sediment sequence extends back approximately 6,000 years. The chronology described in the doctoral thesis combines eight AMS radiocarbon dates with near-surface ²¹⁰Pb ages, checked against ¹³⁷Cs fallout markers. A Bayesian age–depth model was constructed using the P_Sequence function in OxCal 4.2 and IntCal13 calibration (Karlik, 2022).

The analytical framework integrates particle-size distributions, XRF elemental composition, loss on ignition, carbon and nitrogen concentrations, stable carbon and nitrogen isotopes, and n-alkane distributions. Mineralogical and microtextural observations, including XRD, FTIR, Raman spectroscopy and electron microscopy, constrain the interpretation of sediment composition and post-depositional processes. The recent record includes the Chemical Index of Alteration, Chemical Index of Weathering and Plagioclase Index of Alteration, together with organic-source indices such as P_{aq}, P_{wax} and the herbaceous-to-woody index Phw (Karlik et al., 2018, 2021; Karlik, 2022).

The Roman-period presentation supplies preliminary Si/Al, sulfur, sand-fraction and C/N interpretations (Karlik et al., n.d.). These parameters are evaluated as indicators of sediment supply, organic-matter sources and depositional conditions, rather than calibrated temperature estimates. Historical evidence is compared qualitatively with the timing and character of the reconstructed changes. No event-by-event statistical attribution is attempted. The Botoșani sequence provides a prospective comparison across an elevation difference of approximately 1,000 m.

3 Roman period environmental changes and historical context

The preliminary Bolătău interpretation identifies a transition before approximately 50 BCE, involving increased sand input, declining sulfur content and a rising C/N ratio. Increased coarse material may reflect more energetic transport or diminished filtering by ground vegetation. Higher C/N values are consistent with an increased terrestrial organic contribution. Lower sulfur concentrations may indicate changes in oxygen availability, organic supply or sulfur retention, but do not independently establish a warmer or more oxygenated lake. The subsequent interval is described as relatively stable, with increased fluctuations around 150 CE. These observations suggest changing catchment and depositional conditions; attribution of the later variability to cooling remains provisional.

Roman conquest in 106 CE and the subsequent occupation of Dacia provide a regional historical framework. At Colonia Dacica Sarmizegetusa, archaeological sediment biomarkers have been interpreted as indicating warmer and drier conditions during Roman occupation, alongside increasing deforestation. Butiseacă et al. (2025) propose that favourable climatic conditions may have facilitated Roman expansion. Their record offers a regional comparison for the Bolătău interpretation, while also demonstrating that climatic change and human exploitation can affect vegetation together.

Roman expansion is used as regional context rather than evidence of Roman activity within the Bolătău catchment. Likewise, the loss of Dacia and the organised withdrawal under Aurelian around 270–275 CE should not be treated as a direct consequence of cooling. Historical analysis emphasises interacting military, political and economic pressures (Matei-Popescu and Opreș, 2026). The available lake record supports comparison of environmental conditions with this chronology, but does not establish that climate caused either conquest or withdrawal.

4 The Little Ice Age and the Maunder Minimum

The recent Bolătău record provides a more developed reconstruction. The thesis identifies a cold-phase response around 1620–1700 CE, including reduced phosphorus concentrations, minima in P_{wax} and Phw, and a pronounced sand-fraction peak near 1650 CE. The organic-geochemical reconstruction recognises a broader interval of variable conditions around 1640–1760 CE, marked by fluctuations in $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$, low terrestrial-source indices and a relative maximum in P_{aq} (Karlik et al., 2018; Karlik, 2022). The overlapping intervals reflect different proxy responses and sampling resolutions. They are consistent with reduced catchment productivity and altered organic supply during cold decades. Longer lake-ice duration and a shorter growing season provide plausible mechanisms, although neither was measured directly for the historical interval.

Documentary evidence gives this interpretation a regional context. In 1657, snowmelt in the Maramureș Mountains, flooding and renewed freezing impeded the Tisza crossing of George II Rákóczi's army. In 1670, flooding damaged Brașov's city wall, while wet conditions and autumn frosts affected fruit and wine production. The 1672 drought was associated with stopped watermills, rising prices and famine. Prolonged drought accompanied forest fires in 1678, and the winter of 1708/1709 caused severe frost damage and mortality (Stangl and

Foelsche, 2022; accessible manuscript, 2021). These records demonstrate alternating cold, wet and dry extremes during the Maunder Minimum. They support a variable regional climate, rather than continuously cold and humid conditions.

The relatively stable sedimentary interval identified around 1700–1780 CE therefore does not imply an absence of weather extremes. Individual events may be smoothed by sediment sampling, organic-matter integration and age-model uncertainty. Several n-alkane samples integrate multidecadal intervals, with the coarsest reported resolution around 54 years. The 1708/1709 winter cannot consequently be assigned to an individual geochemical anomaly without additional chronological and sampling constraints. Transylvanian accounts also provide regional context rather than direct observations of weather at Bolătău.

5 Early nineteenth century disturbance and conclusions

The strongest evidence for local landscape disturbance occurs around 1811–1820 CE. The thesis reports rising organic content, sulfur and phosphorus anomalies, altered grain-size distributions and weathering indices, and a shift towards herbaceous organic inputs. A layer approximately 3 cm thick containing leaves, needles and small branches reinforces the interpretation of forest removal and enhanced catchment erosion. These findings are consistent with the early nineteenth-century deforestation reconstructed in the published Bolătău study and regional landscape evidence discussed there (Karlik et al., 2018; Karlik, 2022). This disturbance overlaps the 1813–1818 food crisis documented in Transylvania, Banat and Partium. Rus (2023) describes adverse weather, reduced agricultural production, rising prices and hunger, together with warfare and financial difficulties. The overlap places the lake record within a period of regional environmental and social stress. It does not demonstrate that food shortages caused forest clearance at Bolătău, or that this sedimentary disturbance was produced principally by cooling.

The combined evidence distinguishes preliminary Roman-period changes, a seventeenth-century response consistent with climatic stress, and an early nineteenth-century disturbance strongly associated with land use. Historical records clarify the mechanisms through which weather affected agriculture, transport and livelihoods, while sediment composition constrains local ecological and depositional responses. The principal result is an interpretation of climate and landscape change that retains the different spatial scales and temporal resolutions of the two archives. Independent dating of Botoșani and tighter chronological constraints on the Roman-period sequence will allow a stronger assessment of regional coherence.

Acknowledgement

This work was supported by HUN-REN under the Mobility Grant funding scheme (project no. KMP-2025-II/25).

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A systematic synthesis of temperature and precipitation reconstructions in Romania

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KEYWORDS: palaeoclimate, Eastern Europe, temperature seasonality, precipitation variability, atmospheric circulation, multiproxy synthesis

Situated at the confluence of Atlantic, Mediterranean and continental climatic influences, Romania provides particularly well-suited conditions for examining the regionally differentiated expression of broad climatic signals across extended timescales. However, differences in archive type, seasonal sensitivity and chronological control have so far limited the integration of existing reconstructions. The present work synthesises temperature and precipitation reconstructions to identify shared and divergent trends and discuss their possible climatic controls. The synthesis comprises 30 studies (13 quantitative and 17 qualitative) providing explicit temperature and/or precipitation reconstructions and adequate chronological control. The structured narrative synthesis considered the geographical setting, seasonal sensitivity and environmental influences on proxy interpretation.

The records indicate broadly coherent Younger Dryas cooling and early Holocene warming, with a stronger cold-season response. Northwestern pollen estimates suggest cooling of approximately 10°C in the coldest month, compared with 2°C in the warmest month. Throughout the Holocene, several summer-sensitive reconstructions indicate early or middle Holocene warmth followed by cooling, whereas a qualitative cave-ice record indicates autumn–early winter warming towards a maximum around 4–2 ka BP. These contrasting trajectories are consistent with changing seasonal insolation, although differences between northern and southern Carpathian records challenge a synchronous nationwide Holocene thermal maximum. Regarding precipitation, regional contrasts suggest changes in moisture delivery rather than uniform temperature–precipitation relationships. Around 8.2 ka BP, northwestern reconstructions indicate drier conditions, contrasting with enhanced cold-season precipitation in the southwest. During the Little Ice Age, recurrent cooling was accompanied by wetter conditions in the northwest and drier conditions in the southwest, particularly towards the nineteenth century. These differences may reflect shifts in westerly storm tracks, changing Atlantic and Mediterranean moisture contributions and rain-shadow effects, although differing seasonal targets and chronologies limit direct comparisons.

Overall, the findings support a seasonally and regionally differentiated climatic evolution. Orbital forcing provides a plausible background for temperature changes, while atmospheric circulation may explain precipitation redistribution. Nevertheless, the concentration of studies in mountain and karst environments limits extrapolation to the Romanian lowlands, highlighting the need to improve spatial coverage, comparability among future reconstructions and their integration into wider European syntheses.