Ethnobotany of Eastern Europe: The Carpathian Region

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Introduction

The Carpathians are the second largest mountain range in Europe and provide multiple ecosystem services of regional significance (Kholiavchuk et al. 2024). The Carpathian Mountains region lies over parts of the territories of seven Central and Southeastern European countries, and the mountain chain causes main alterations in the temperate climate specific to the latitudes between 43° and 49° N (Cheval et al. 2014).

The Carpathians at their highest altitude are only of the similar height as the middle region of the Alps, with which they share a common appearance, climatic conditions, and biodiversity. The flora of the Carpathian Mountains and lowlands is rich, containing over 6000 described native species; with introduced and invading flora, it counts more than 7500 species (Bojnansky and Fargasova 2007). At least 3808 vascular plant species and subspecies, represented by flowering plants, conifers, and ferns, compose the native flora of the Carpathian Floristic Subprovince (Tasenkevich 1998).

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Geography and Geology

The Carpathians are a wide, crescent-shaped mountain ridge located in Central and Eastern Europe, extending for about 1450 km in a system of parallel structural ranges eastward from the Danube Gap near Bratislava in Slovakia, southward to Brasov in Romania, and southeastward to a part of the Danube Valley, called the Iron Gate near Orsova in Romania and covering the area of 209,256 square km. (Błażejczyk et al. 2020; Bojnansky and Fargasova 2007), over parts of the territories of the Czech Republic, Slovakia, Hungary, Poland, Ukraine, Romania, and Serbia (Cheval et al. 2014).

The Carpathians comprise of several geologically and orographically distinct mountain ridges. The highest part is the Tatra Massif, characterized by typical alpine relief, which has more than 50 peaks with an elevation above 2000 m, the highest one is Gerlachovsky stit (Mount Gerlach), 2655 m ASL, located in Slovakia. In the Eastern Carpathians, Chornohora is the highest ridge, with six peaks exceeding 2000 m (Hoverla 2061 m ASL) (Błażejczyk et al. 2020). The name "Carpathians" was first mentioned as Karpates oros in the second century by the Greek geographer Ptolemy (Ptacek et al. 2011).

The Carpathians are designated by a mid-mountainous relief shaped by rivers and slope erosion. Pleistocene glaciations occurred in the Tatras (Ptacek et al. 2011). Despite the fact that commonly referred to as a mountain chain, the Carpathians do not actually form an uninterrupted chain. Rather, they are formed of several orographically and geologically distinctive groups, presenting as great a structural diversity as the Alps. The Carpathians, which only in few locations exceed an altitude 2500 m, lack the bold peaks, extensive snowfields and glaciers, high waterfalls, and the various large lakes which are common in the Alps. The Carpathians are split up into several mountain blocks separated by basins. Water runoff from the mountain chain escapes for its most part into the Black Sea through the rivers Danube and Dniester. From the northern slopes and the large Big Poland Lowland, it falls into the Baltic Sea through the Vistula River (Bojnansky and Fargasova 2007).

The Carpathians play a significant role in Romania (40.1% of national territory) and Slovakia (77.8%). In the latter case, three hills represent the mountains in the country's state symbol (Turnock 2006).

No consistent geomorphologic division of the Carpathians exists currently. In the Czech Republic, Slovakia, and Poland, the division into the Western, Eastern, and Southern Carpathians is accepted. In Romania, they are classified as Northern, Eastern, Southern, and Western Carpathians. The Predeal Pass is considered as the division between the Eastern and Southern Carpathians (Ptacek et al. 2011).

Similarly to the Alps, the Carpathians have risen from a Mesozoic geosynclinal sea. The curved shape of the range is caused by occurrence of older, more resistant parts of crust, representing the Bohemian Massif in the northwest, the Ukrainian shield in the northeast, and the Moesian Platform in the southeast, known as Tisia Massif (in the Danube basin). The folding had several stages and was completed in the Tertiary. The Southern Carpathians were formed during the final phase (Ptacek et al. 2011).

The Carpathian Mountains are composed of three geological belts. The outer flysch belt is formed by sedimentary rocks such as sandstone, claystone, and pudding stone. The central belt, where the highest peaks occur, comprises metamorphic and igneous rocks. The inner belt comprises mostly volcanic rocks, which are characteristic for the Western Carpathians. In the Eastern Carpathians, the flysch belt is more established. The Southern Carpathians lack both the outer flysch and the inner volcanic belt. The entire area has risen since the Pliocene by about 1000 m (Ptacek et al. 2011).

The Vrancea Mountains, a mountain range in the Curvature Carpathians in Romania, is characterized by an increased seismic activity. A catastrophic earthquake (magnitude 7.2) had its epicenter in these mountains, causing over 2000 death cases (Ptacek et al. 2011).

Archaeological evidence indicates human occurrence in the region dating back to 100,000 years before present (Fontana 2021).

Climate

The climate of the Carpathians and its surrounding lowlands and basins is temperate continental, increasingly intensive eastwards. It has an active variability and is well emphasized at monthly scale for variables like air temperature, wind, sunshine duration, and relative humidity. The mountain range, however, is more humid than the lowlands and basins. Precipitation levels increase with altitude and lowered from west to east. The western regions averagely display an annual precipitation of 700–800 mm, while the southeastern ones 350–400 mm and mountainous parts 1000–1200 mm, reaching up to 2100 mm in the Tatras. Due to the Danube river, almost entirely the area belongs to the Black Sea catchment, with only the northern and northwestern parts related to the Baltic Sea watershed basis (Oder) (Cheval et al. 2014; Ptacek et al. 2011).

Alterations in the precipitation patterns are more complex, with elevating or cooling elevation or lowering regimes randomly distributed across various parts of the Carpathian Mountains. The extended drought occurrence was recorded for inner mountain valleys, the northern foothills of the Western Carpathians, and the southeastern macroslopes of the Eastern Carpathians and the Southern Carpathians. The severity of droughts has increased mostly in spring and early summer months (Kholiavchuk et al. 2024).

The following vertical climate zones were categorized in the Carpathians: moderately warm (<700 m ASL), moderately cool (700–1100 m ASL), cool (1100–1550 m ASL), very cool (1550–1850 m ASL), moderately cold (1850–2200 m ASL), and cold (>2200 m ASL). These zones correspond to the ones occurring in the European Alps: <1050 m ASL—coline belt, 1050–1390 m ASL—montane belt, 1390–1880 m ASL—subalpine belt, and 1880–3250 m ASL—alpine belt (Błażejczyk et al. 2020).

Climate alterations since the 1960s resulted in the warming of the Carpathians, with the highest temperature increase in the Western Carpathians (Low Tatras

Mountains; on average, +2.1 °C) and the lowest (about +1.2 °C) in the Southern and Eastern Carpathians. Elevation-dependent warming, as also recorded in other mountain regions, also occurs in the Carpathians (Kholiavchuk et al. 2024).

The Carpathians are a barrier for air masses that significantly modify the air temperature. In the Northern Carpathians, the southward slopes are warmer in comparison with northward ones. In the Eastern and Southern Carpathians, there are thermal differences, which alter in accordance with the season between the westward and eastward slopes. Bioclimatic differences between the northward and southward slopes were also revealed (Cheval et al. 2014; Błażejczyk et al. 2020).

The maximum and minimum air temperatures were revealed for the entire Carpathians, although some variability concerning regions and seasons occurs. Summer maximum temperatures have mostly elevated since the 1960s. Minimum temperatures were also recorded as generally increased during the seasons, while less pronounced in the Eastern and Southern Carpathians in spring and summer periods. Higher temperatures have also raised the risk of wildfires (Kholiavchuk et al. 2024).

Flora and Vegetation

The forested part of the Carpathians makes a significant contribution to Europe's natural heritage; ecosystems of the mountains demonstrate a unique genetic diversity and a variety of plant species. Over half (106,183 km^2) of the studied territories are forested, comprising 49.44% of broad-leaved forests, 27.43% of coniferous forests, and 23.13% mixed forests. The highest degree of forest cover is found in the Ukrainian Carpathians (91%). Slovakia is 40.9% forested; broad-leaved forests occupy 58.2% of its area, and the ratio of coniferous forests is 41.8%. Due to the Carpathian flora, Romania possesses a great biodiversity, with 3100 native plant species, including 60 tree species; 69% of its forested areas are covered by broad-leaved forests and by 31% of coniferous forests (Gal and Racz 2008).

The flora of the Carpathian Mountains comprises several unique species, especially in the southeastern where the impact of Quaternary climatic cooling was less noticeable. Forests have been best preserved in the eastern part. At some point, the entire Carpathians were covered with forest and topped with meadows and rock fields. Except for that of the Low Beskyd, the vegetation of the Ukrainian Carpathians is richer than in the Western Carpathians and comprises numerous Balkan and Transylvanian species and some endemic forms. All the mountain vegetation belts are represented in the Ukrainian Carpathians (Bojnansky and Fargasova 2007).

The lowest belt, up to an altitude of 500–600 m, is represented by deciduous and mixed forests, comprising mostly oak and some hornbeam, maple, linden, elm, birch, and pine. Above it lies the belt of mountain forests. Beech forests occur exclusively in Transcarpathia, except of its northeastern and eastern parts, and in the upper Sian River basin; in other parts of the Ukrainian Carpathians, mixed and coniferous forests predominate. The undergrowth of the beech forests consists of

elder, mezereum, raspberry, currant, honeysuckle, and willow. The upper level of the beech forests is determined at 1100–1200 m. Other mountain forests form a lower, mixed belt, which at an altitude of 900–1200 m mostly comprises beech, spruce, and fir, with an undergrowth similar to that of the beech forests; and a higher, spruce belt, with an admixture of fir, pine, larch, cembra pine, and ash. The upper limit of the Carpathian forests is 1450–1600 m, represented by individual trees, brush, and meadow (Bojnansky and Fargasova 2007).

Above the forests occurs a belt of highland pastures—meadows and brush with subalpine (up to 1750–1850 m) and alpine vegetation. The characteristic plants of the subalpine belt include mugo pine, green alder, rhododendron (*Rhododendron kotschyi*), and dwarf juniper (*Juniperus nana*), which often form a large, hardly penetrable brush, particularly in the Gorgany Mountains and the Maramureş-Bukovynian Upland. All the higher ridges are covered with grasslands, except the Gorgany. In the beech forest belt, grasslands completely cover the ridges above 1100–1200 m, while in the pine forest belt, their lower limit is 100–150 m higher, and they are partly taken over by brush, mainly by dwarf pines. Meadows are found rarely in the Gorgany. The variety of plants growing in the meadows expands towards the east, being the highest on chalky soils (Bojnansky and Fargasova 2007).

Phytodiversity and Medicinal Plants of the Ukrainian Carpathians

The Ukrainian Carpathians are a unique geographical region with natural conditions, flora, vegetation, and traditions of using their resources that are different from other regions. Due to the mild climate and various types of soil, the flora and vegetation here are very rich. The study of the flora and vegetation of the Ukrainian Carpathians, especially the rarity component, has a long history. The most complete assays on the phytodiversity of the region can be found in the works of prominent Ukrainian scientists V.I. Chopyk, S.M. Stoyko, K.A. Malinovsky, V.I. Komendar, S.S. Fodor, L. Tasenkevich, I. Chorney, V. Kricsfalusy, and some other researchers.

The floristic diversity of the Ukrainian Carpathians comprises more than 2500 species and subspecies of vascular plants, which consist of about 40% of the vascular plants of Ukraine (Tasenkevich 2005; Chopyk and Fedoronchuk 2015). It is a large natural center of floristic diversity with numerous rare, relict, and endemic plant species. According to the latest data, there are 78 endemic accepted species belonging to 51 genera, 29 families, 15 orders, and 2 classes of vascular plants (Novikov 2023). In the Ukrainian Carpathians, 151 species of vascular plants are subject to national or international protection and 272 species are under regional protection (Kricsfalusy and Budnikov 2007).

Climate changes in recent decades pose a real threat to habitats and even the disappearance of many of them. This especially applies to alpine species that are on the verge of their distribution in the Ukrainian Carpathians and grow mainly in the largest mountain massifs, such as Chornohora, Svydovets, Chyvchyny, and Marmarosh (Kobiv 2018). Most of the taxa, which have centers of their distribution in the alpine and subalpine vegetation belts of the East Carpathians in the Ukraine territory, are threatened elements of the Ukrainian flora (Cherepanyn 2019; Tasenkevich et al. 2022).

The Ukrainian Carpathians are one of the most ecologically pure regions of Ukraine with a total forest cover of more than 50%, and in some areas—more than 70% (in the basins of the Teresva, Upper Tysa, Limnytsia, and Bystrytsia) (Kruglov et al. 2013). The complexity of the topography of the mountains, the difference in hydrothermal conditions on the northeastern and southwestern macroslopes, and a large number of tree species—all led to the formation of the most diverse types of forests in the Carpathians. The spatial arrangement of plant communities of the Carpathians has a clearly defined altitudinal zoning, which is determined by the ratio of air temperature and amount of precipitation. Based on this ratio, seven geobotanical altitudinal zones of the Ukrainian Carpathians are distinguished (Prots and Kagalo 2012). The general regularity of the high-altitude vegetation zones here is that the upper limit of certain types of forest communities is higher on the southwestern macroslope of the Carpathian Mountains and is lower on the northeastern macroslope. In addition, the boundaries of such natural vegetation belts are now largely altered by human activity. For example, beech forests in the southern regions grow up to 1000 m above sea level, while on the northeastern macroslope, only up to 600 m above sea level. At the same time, the border of the subalpine belt is almost the same in both parts.

Currently, the forests of the Ukrainian Carpathians are at different stages of vegetation succession, from pioneer to stable phytocenoses. Substantial changes in the structure of the region's forests began in the middle of the last century when methods of continuous felling and artificial forest regeneration were actively introduced into forestry. However, ancient natural forests and primeval forests (especially primeval beech forests) are preserved in the protected areas. They have complex spatial and vertical structures, great species diversity, and are of significant value for monitoring the natural alterations of the region in the process of climate change (Korol et al. 2022). Almost 24,000 ha of Carpathians primeval beech forests are under the protection of UNESCO and its buffer zone occupy about 35,000 ha. Tree cutting and sanitary cutting are not allowed in the buffer zones (Ancient. . . 2007).

The lower forest zone extends from the foothills up to 700 m above sea level. In the foothills, the main forest-forming species is oak. The forest is usually mixed and multitiered. A large number of other broad-leaved species are mixed with *Quercus robur* L. and *Q. petrae* (Matt.), such as *Tilia cordata* L., *Acer pseudoplatanus* L., *A. platanoides* L., *Fraxinus excelsior* L., and *Carpinus betulus* L., and in some places, *Fagus sylvatica* L. is abundant. There are also *Cerasus avium* (L.) Moench, wild apple trees, and common pears, which are a valuable food source for many animals and birds. Beech is already appearing at these heights. The beech-hornbeam forests of Transcarpathia are especially beautiful in spring when Carpathian saffron (*Crocus heuffelianus* Herb.) blooms profusely, which the local population sometimes collects for culinary purposes. This plant is most common in the highlands of the Ukrainian Carpathians, where the largest plant populations are located (Fig. 1). It is listed in the Red Book of Ukraine.

In the foothills, such forests are often separated by large areas of herbaceous and shrubby plant communities. Valuable food and medicinal plants such as *Rubus hirtus* Waldst. & Kit., *Juniperus communis* L., *Crataegus* spp., and *Rosa* spp. often grow

Fig. 1 Beech-hornbeam forest with *Crocus heuffelianus* near village Pushkino, Transcarpathia. (Photo V. Minarchenko)

on such lands. The local population traditionally uses them for food and medicinal purposes (Fig. 2). Large areas here are sometimes occupied by agricultural land (Fig. 2).

In the Ukrainian Carpathians, monodominant and mixed beech forests cover the Carpathian Mountains to 900 m above sea level. Beech rises even higher, up to 1150–1320 m. However, here it is only one of the components of mixed coniferous-deciduous forests. Mixed beech-fir-spruce and fir-beech-spruce forests are formed mainly on poor soils with a significant presence of *Abies alba* Mill., *Acer pseudo-platanus* L., *Fagus sylvatica* L., and *Picea abies* (L.) H.Karst. With increasing height above sea level, the role of beech in phytocenoses decreases, and the share of spruce increases. Directly, such forests are not rich in the diversity of medicinal plants, but a large number of medicinal plants grow here in the forest or post-forest areas (felling, forest edges, forest clearings, post-forest meadows, etc.). The most common among them are *Rubus hirtus, R. nessensis* Hall., *Sambucus nigra* L., *Sorbus aucuparia* L., *Digitalis grandiflora* Mill., *Hypericum perforatum* L., *H. maculatum* Crantz, *Arnica montana* L., and species of the genus *Thymus* L. Occasionally can be found here *Scopolia carniolica* Jacq., *Gentiana lutea* L., and *Atropa bella-donna* L., which are rare and listed in the Red Book of Ukraine (Fig. 3). These are valuable medicinal plants used both in traditional and official medicine (Fig. 3).

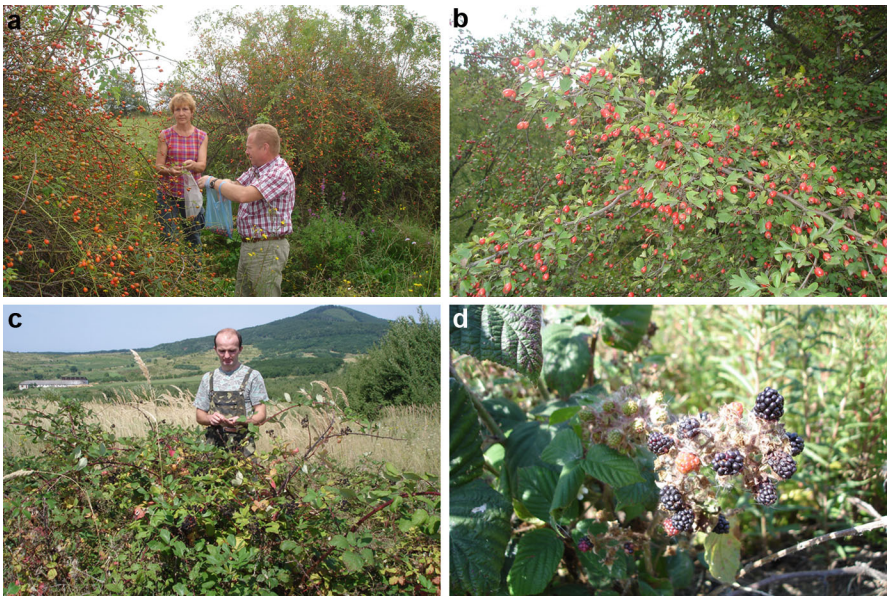

Fig. 2 (**a**) Harvesting rose hips, Transcarpathia. (Photo V. Minarchenko). (**b**) Hawthorne bears abundantly, Transcarpathia. (Photo V. Minarchenko). (**c** and **d**) The most common blackberry in Zakarpattia is the rough blackberry (*Rubus hirtus*), Transcarpathia. (Photo V. Minarchenko)

Fig. 3 *Atropa bella-donna* on a beech-spruce clearing, near the village Lyuta, Zakarpattia region. (Photo V. Minarchenko)

Arnica montana occurs sporadically from the lower forest zone to the alpine zone (nearly 2000 m above sea level) (Minarchenko et al. 2011). The highest indicators of its abundance were noted in the post-forest meadows and fellings in the height range of 900–1100 m above sea level, although even 40 years ago, the highest number of arnica individuals was in post-forest meadows in the mid-mountain zone from 500 to 1500 m above sea level. This indicates that arnica populations are undergoing

Fig. 4 Glade with *Arnica montana* and *Gentiana lutea* near the village Lopukhovo, Zakarpattia region. (Photo V. Minarchenko)

intense impact under the influence of anthropogenic factors and climate change. Above 800 m ASL, *Gentiana lutea* sometimes occurs in post-forest meadows with arnica (Fig. 4).

The upper forest boundary is formed by high mountain monodominant spruce forests with a small species diversity (up to 1500 m above sea level). *Rosa pendulina* L., *Rubus hirtus, Lycopodium annotinum* L., and *Huperzia selago* (L.) Bernh. are sometimes found in deforestation plots, meadows, and forest edges. *Vaccinium myrtillus* L. thickets are well developed in slightly shaded areas of the spruce forest. Under the canopy of trees or on the edge, blueberries grow well, sometimes reaching 60 cm in height (Fig. 5a and b), although in mountain valleys it usually does not exceed 20 cm.

The subalpine crooked forest dominated by mountain pine (*Pinus mugo* Turra) is limited in distribution in the Ukrainian Carpathians and occupies only the summit slopes and peaks of the highest ridges (Fig. 6). Here also often forms continuous thickets of *Juniperus sibirica* Burgsd., *Vaccinium myrtillus* L., and *V. uliginosum* L. with the involvement of *V. vitis-idaea* L. and some others (Fig. 7). Grass cover is formed mainly by cereals, among which *Nardus stricta* L. most often dominates (Prots and Kagalo 2012).

In the subalpine zone, mountain meadows and polonynas are widespread over large areas. Subalpine vegetation occupies the largest area of the Carpathian highlands, slopes, and peaks up to 2000 m. Almost half of the area of high-altitude meadows in the subalpine zone of the Ukrainian Carpathians highest ridges (1500–1900 m ASL) is occupied by low-growing dense turfy *Nardus stricta* thickets, which were formed as a result of long-term grazing on the site of primary high-altitude meadows, shrubs, and forest (spruce and beech) groups. The use of such meadows for pasture has decreased significantly in recent years, but in some areas, the tradition of summer sheep or cattle keeping on mountain pastures has been preserved. Shepherds care for the sheep and process milk into cheese (brynza, etc.) (Fig. 8).

Fig. 5 (**a** and **b**) Blueberry thickets on the edge of a spruce forest (1600 m ASL) near the village Lopukhovo, Zakarpattia region. (Photo V. Minarchenko)

Fig. 6 Crooked forest with *Pinus mugo* in Gorgany. (Photo V. Minarchenko)

Such high-altitude meadows are located on gentle slopes or open areas and sometimes among thickets of mountain pine above the upper limit of the forest. Species diversity here is insignificant, but such communities include medicinal plants *Arnica montana, Gentiana lutea, Hypericum maculatum, Hypericum richeri subsp. grisebachii* (Boiss.) Nyman, *Potentilla erecta* (L.) Räuschel, and *Rhodiola rosea* L (Fig. 9).

Fig. 7 Thickets of *Juniperus sibirica* and *Vaccinium myrtillus* on the slopes of the Svydovets ridge. (Photo V. Minarchenko)

Sometimes in such areas, there are dense thickets of *Vaccinium myrtillus, V. uliginosum,* and *V. vitis-idaea*, the fruits of which are actively harvested by the local population for their own needs and sale (Fig. 10).

Another popular species in traditional medicine is lichen *Cetraria islandica* (L.) Ach., which has long been used by the local population to treat bronchopulmonary and gastrointestinal diseases. In the Ukrainian Carpathians, its main habitats are associated with the highlands of Chornohora and Svydovets (Fig. 11).

The greatest diversity of herbs is characterized by mid-mountain meadows, with species richness reaching 80 species in some areas. The greatest abundance of herbs in such meadows is observed in the range of 500–900 m. These meadows were formed under the influence of economic activity in post-forest areas, and their long-term existence is due to the practice of regular mowing, less often used for pasture. The grass stand of such meadows is multitiered, dominated by cereals and forbs, which develop especially abundantly in late spring and early summer. Such meadows are rich in a variety of medicinal plants that form a bright aspect. In particular, *Achillea millefolium* L., *Arnica montana* L., *Betonica officinalis* L., *Hypericum perforatum* L., *Euphrasia* spp., and some orchid species such as *Gymnadenia conopsea* (L.) R.Br., *Epipactis palustris* (L.) Crantz, and *Listera*

Fig. 8 Barns for keeping sheep on summer pasture. Blysnytsia, Zakarpattia region. (Photo V. Minarchenko)

ovata (L.) Bluff & Fingerh are sometimes abundant in such meadows (Figs. 12, 13, and 14).

On xeromesophytic grasslands with a dominance of cereals, plants of the genus *Thymus* L. (thyme) often form dense aggregations, the raw materials of which are traditionally used by the local population to treat respiratory diseases. The most common of these are *T. pulegioides* L., *T. alternans* Klokov, and *T. alpestris* Tausch ex A.Kern., which usually grow only in the highlands. In depressions and along rivers and streams, aggregations are formed by *Bistorta officinalis* Delarbre, *Filipendula ulmaria* (L.) Maxim., *Mentha longifolia* (L.) Huds., and occasionally *Valeriana officinalis* L.

The use of medicinal plants in folk or traditional medicine by the people of the Ukrainian Carpathians has a long history. This treatment grew out of a combination of knowledge, traditions, and beliefs of the indigenous population, i.e., it is the result of the material and spiritual life of the Carpathians and reflects the character and distinctive culture of these people. This knowledge was largely the basis for the use in official medicine of valuable medicinal plants that grow here. The history of the healing properties and use of medicinal plants of the Carpathian region in traditional medicine is described in the publications of many researchers.

The most complete data on the medicinal properties and peculiarities of collecting and using medicinal plants of the Carpathians are presented in the works of the

Fig. 9 *Hypericum maculatum, Hypericum richeri subsp. grisebachii*, and *Potentilla erecta.* (Photo V. Minarchenko)

Fig. 10 *Vaccinium myrtillus, V. uliginosum*, and *V. vitis-idaea* in the polonyna Gostra, Zakarpattia region. (Photo V. Minarchenko)

Fig. 11 *Cetraria islandica* on the slope of Mount Hoverla. (Photo V. Minarchenko)

Fig. 12 A variegated meadow with *Achillea millefolium* and *Hypericum perforatum*, near the village Nyzhni Vorota, Zakarpattia region. (Photo V. Minarchenko)

Transcarpathian scientist Vasyl Komendar, who described 400 species of local medicinal plants (Komendar 2007). However, this is not a complete list of medicinal plants used by the local population. The number of species is much higher, as traditional knowledge of plant names does not always coincide with their scientific names. For example, there are several species of the genera *Achillea, Euphrasia,*

Fig. 13 Mixed-grass and cereal meadow with numerous species of the orchid family. The village of Sheshory, Ivano-Frankivsk region. (Photo V. Minarchenko)

Fig. 14 Mountain meadow with arnica near the village Zelena, Ivano-Frankivsk region. (Photo V. Minarchenko)

Hypericum, Mentha, and *Thymus* which are not recognized by the majority of the population to the species level but are used in herbal medicine.

Human Plant Use

Forest expansion and species alterations have been observed since Holocene deglaciation, impacted by timber uses, settlements, cropland development, and, since the Bronze Age, pasture activities. At higher elevations, early conifer successors have been increasingly substituted by Norway spruce (*Picea abies*), silver fir (*Abies alba*), European beech (*Fagus sylvatica*), and hornbeam (*Carpinus betulus*), while oaks have been always present in the Carpathian foothills. Norway spruce afforestation was favored in the last two centuries, and timber application peaked (Kholiavchuk et al. 2024). By decreasing the upper limit of the forests, humans have expanded the area of grasslands, but excessive pasturing has diminished the plant biodiversity (Bojnansky and Fargasova 2007).

The alpine belt of the Carpathians is designated by high mountain pastures, the subalpine layer by dwarf pine growth, the upper forest layer by spruce, and the lower one by beech. The foreland belt is denoted for oaks and elms. The natural vegetation layers are related to economic land uses: the foreland belt is used for growing wheat and potato, the lower forest belt for oats and potato cultivation (up to 1000 m), and the upper forest and the subalpine belts for pastoral use (Bojnansky and Fargasova 2007).

Recent transitions from agriculture to forest land management caused a further growth in forest cover (+1 to +14% in different countries), though past forest practices and recent environmental alterations have damaged forest vitality in several regions; climate warming already is the reason of shifts in tree lines and species distributions, and it triggers pest outbreaks and impacts tree–water connections (Kholiavchuk et al. 2024).

Around 65% of the Carpathian forests are applied for economic purposes, where main activities involve, among others, logging and hunting. Half-century ago, so-called resort forests that aimed at different recreational purposes (resting, walking, and excursions), important tourist attractions, in the region started to increase both in number and area. In addition to provision of wood, forests nowadays contribute significantly also to energetics, environmental protection, and welfare (Gal and Racz 2008).

Indigenous, ethnographic communities of the highlanders in the Eastern Carpathian Mountains, including Hutsuls in Hutsulshchyna, Boykos, in the Bystrytsia Solotvynska River Basin, and Lemkos, in the Low and Middle Beskyd Mountains, are self-sufficient in terms of their nutritional needs, relying on a diversity of habitats nearby. Food is grown, gathered, stored (dried, pickled, canned, and fermented), and further used by the highlanders (Fontana 2021).

Hutsuls, traditional pastoral highlanders of the Eastern Carpathians, have maintained alpine grasslands (polonynas) through mountain shepherding of cows and sheep. There is a continuing threat of cultural loss of this practice due to low economic competitiveness and increasing disinterest among younger generations. Mountain shepherding and some other traditional ecological practices, such as

collecting of non-timber forest products, like wild edible plants and mushrooms, although threatened, have survived (Fontana 2021). The major economic activities of both Romanian and Ukrainian Hutsuls are small-scale mixed farming and non-wood forest product exploitation (Mattalia et al. 2020).

Recent studies concerning the southeastern Hutsul region demonstrate impact of sociopolitical (wars) and geographical (borders) changes, trends, and differences seen in uses of local ethnobotanical plant species of cultural importance (Fontana 2021; Mattalia et al. 2020; Pieroni and Soukand 2017; Soukand and Pieroni 2016; Stryamets et al. 2021). Ukrainian Hutsuls from Northern Bukovyna reported around 30% more plant taxa than Romania Hutsuls. The latter group mentioned almost exclusively locally available plants, whereas the former group reported some plants not mentioned by Romanians such as *Aloe vera, Maclura pomifera,* and *Aronia melanocarpa.* As Hutsul cultural markers in both Northern and Southern Bukovyna might be considered the widely used plant species—*Vaccinium myrtillus, Rubus idaeus*, and *Urtica dioica.* Among Romanian Hutsuls, *Fagus sylvatica* wood is commonly utilized for smoking pork meat, which is one of the most traditional Hutsul preparations, as well as to flavor soups (Mattalia et al. 2020).

St. John's wort (*Hypericum perforatum*), bilberry (*Vaccinium myrtillus*), raspberry (*Rubus idaeus*), mint (*Mentha spp*.), and arnica (*Arnica montana*) share high cultural importance in the Hutsul landscape (Soukand and Pieroni 2016; Pieroni and Soukand 2017; Mattalia et al. 2020; Fontana 2021) on both sides of the Ukrainian-Romanian border, occupying diverse habitats (Fontana 2021).

Jam, a known food preparation, predominates in Romania and can be prepared from eight taxa, five of which were common to both communities (*Fragaria vesca, Rubus caesius, Rubus idaeus, Vaccinium myrtillus*, and *Vaccinium vitis-idaea*). Among the taxa used for jams, exclusively prepared by Romanian Hutsuls, are young sprouts of *Picea abies*, which are collected in June and might be also utilized for the preparation of medicinal syrup, and the petals of *Rosa rugosa* and *Rosa centifolia*, which find a use for jams and teas, almost exclusively by Romanian Hutsuls. The flowers of *Taraxacum officinale* were also applied for the preparation of jam by the latter (Mattalia et al. 2020).

Seasoning is another common application of wild food plants, particularly of *Thymus spp.* and *Armoracia rusticana*, which are used in both Hutsul communities. *Armoracia rusticana* is added by Ukrainian Hutsuls into "kvashennya," which is a lacto-fermented preparation of cucumbers, tomatoes, cabbage, or other vegetables, known in Romania as "muraturi." For this preparation, Hutsuls use *Armoracia rusticana* roots (in Ukraine also leaves are utilized) and *Quercus spp.* (young branches in Romania and leaves in Ukraine), and *Carum carvi* only in Ukraine. Various cultivated plants (cucumbers, carrots, garlic, cabbage, cauliflower, as well as mushrooms in some cases) are added to it, which is later fermented (Mattalia et al. 2020).

Compote, which is made by boiling berries (*Fragaria vesca, Rubus idaeus, Rubus caesius, Vaccinium myrtillus, and Vaccinium vitis-idaea*) in abundant water and later removing them to drink the flavored liquid, is another food preparation, known on both sides of the Ukrainian-Romanian border. The compote can be prepared with or without adding sugar (e.g., *Vaccinium myrtillus* compote); berries

are either eaten as a dessert or thrown away. It also might be prepared as a preserve for wintertime (Mattalia et al. 2020).

Quantitative ethnobotanical indices were recently received within the fieldwork in villages, surrounding Verkhovyna, the historical heart of Hutsulshchyna (Fontana 2021), for 108 species from 79 genera and 48 families, including 23 species of cultivated plants, 9 species of mushrooms, and 2 species of lichens.

The diversity of observed plants' applications by Ukrainian Hutsuls comprises food (alcoholic beverage, fruit, recreational beverage, seasoning, vegetable, tea, and mushrooms), medicinal (tinctures, topical treatment, ground forms), as ecological markers, symbolic, toxic, veterinary, textile, repellant, and economic ones (Fontana 2021).

The plants characterized with the highest number of uses comprise cannabis (*Cannabis sativa*), followed by chokeberry (*Aronia melanocarpa*) and apple (*Malus spp.*). Cannabis was historically applied as a textile (shirts, bags, and woven thread) but is currently outlawed in Ukraine. Cannabis was also used as a tea, processed as an oil, as a medication, and in rituals. Its symbolism and use was involved in the celebration of St. Andrew's feast day. Chokeberry (*Aronia melanocarpa*), typically consumed as a fruit, is used for tincture preparation or brewed into a tea, and other recreational beverages such as kvass and wine (Fontana 2021).

Culturally important plant species are used by Hutsuls in a variety of traditional foods. Many commonly collected berries are traditional foods including *Vaccinium spp.* (*V. myrtillus and V. vitis-idaea*), *Rubus spp.* (*R. idaeus and R. caesius*), *Ribes spp.* (*R. nigrum and R. uva-crispa*), *Fragaria vesca*, *Sambucus nigra*, *Aronia melanocarpa*, and *Sorbus aucuparia*. These berries are eaten fresh, frozen, and dried, or cooked into jams, jellies, fillings for traditional dumplings, syrups, and sauces, or used in recreational drinks including fermented kvass, as well as juice, uzvar (a compote), and wine (Fontana 2021). A special mode of food preparation in Ukraine is kvas(s), a beverage made from fermented grain with a low alcohol yield; birch sap may be added as its ingredient. Such a beverage is often flavored with berries and fruits, especially *Aronia melanocarpa, Sorbus spp.,* and *Vaccinium vitis-idaea* (Mattalia et al. 2020). The culturally important bilberry (*Vaccinium myrtillus*) is cooked into varenyky (dumplings) and used as a flavoring in alcoholic tinctures, fruits, and juice, being the most popular product for sale and household consumption (Fontana 2021).

Chenopodium album and *Rumex acetosa* are still used in soups by Hutsuls. Young shoots of these herbs are recorded to be fried with onion. *Ribes spp.* (including *R. nigrum and R. rubrum*) are utilized in the fermentation of cucumbers, as well as in various recreational drinks (juice, tea, and wine), jam, and marmalade. *Thymus serpyllum* finds a use as seasoning in soups and traditional foods as well as herbal remedy for treatment of cough (Fontana 2021).

Ninety-two taxa were used by Ukrainian Hutsuls for medicinal purposes: two of the most cited medicinal categories concern preventative care, such as a source of vitamin C and regulating blood pressure, while the other three address treatment purposes (stomach, fever, and wounds) (Fontana 2021).

Hutsul traditional dishes incorporate an important dairy product from polonynas (polonynska bryndza), a cheese made from Carpathian cows or sheep, as well as many mushroom species (particularly *Boletus edulis* and *Cantharellus ciborium*), used in cooking and in holiday meals. They are added to traditional dishes such as banosh and

kulesha, and their main components comprise corn flour (*Zea mays*) and polonynska bryndza. Forest mushroom soup is also a very common first course (Fontana 2021).

Threats to Plant Diversity and Use

Forests of the Carpathians cover a large area and are impacted by diverse environmental conditions and contrasting historical developments. The risk of forest damage is the highest in monodominant Norway spruce forests. European beech forests are more adaptable unless affected by summer droughts. In upcoming decades, expanded dominance of broadleaves within Carpathian forests is expected. Maintenance and promotion of silver fir and mixed European beech forests should be encouraged with respect to forest stability, biodiversity, and economic sustainability (Kholiavchuk et al. 2024).

With a total area of 9.92 mln hectares, Carpathian forests account more than 70% of the total forested land in Slovakia and Romania, with Romania alone maintaining over 45% of all Carpathian forests (Kholiavchuk et al. 2024).

The forests' ecosystem during last quincentennial period was significantly altered due to economic activities in the Carpathians; anthropogenic impact, such as agricultural expansion, mining, wood, and the related chemical industry, caused deforestation, forest fragmentation, and degradation in some locations. The current species composition (with European beech dominating in more than 53% of Carpathian forests; Norway spruce, in about 30%; silver fir, in only 2.4%; and oaks, in 15%) is an outcome of such practice (Kholiavchuk et al. 2024).

Felling may lead to serious damage in some regions (e.g., felling precious tree species without proper replacement, increased threat of erosion due to clear-felling, and elimination of ecological corridors), and therefore, forest owners should assume more responsibility for the long-term maintenance of this natural asset of the Carpathians. In the recent decades, the so-called "wind-felling" has occurred more frequently, mainly in the coniferous forests of the high and medium-high mountains. Such damages occur almost everywhere throughout the Carpathians (Gal and Racz 2008).

In Ukrainian Carpathians, one of the most valuable regions of Ukraine, rich in raw materials, possessing the least transformed vegetation, about 741 species of medicinal plants are grown with only 36 species being cultivated and introduced. The raw material of about 50 wild species is harvested in significant quantities for medicinal and food purposes (Minarchenko et al. 2019). The following medicinal plant materials are harvested in quantities exceeding 5 tonnes annually: *Crataegus spp., Hypericum spp., Rosa spp., Rubus spp., Sambucus nigra,* and *Vaccinium spp.* (Minarchenko 2013).

Current regional ecosystem challenges, including illegal logging, commercial harvesting, and climate alterations, continue to impact collection practices among Ukrainian Hutsuls, living around Verkhovyna, and conservation status of endangered culturally important plants (*Allium ursinum, Atropa belladonna, Colchicum autumnale, Gentiana lutea, Gentiana punctata, Orchis maculata, Platanthera bifolia, Rhodiola rosea, Pinus cembra, and Pinus sylvestris*) and their habitats (Fontana 2021).

Autumn and spring burns of the vegetation remnant for pastures aimed at improving at the polonynas (subalpine and mountain meadows) within Ukrainian Carpathians is another threat that causes a significant harm for phytodiversity, since bilberry and cowberry resources at such sites are restored at least for 6–7 years, and the populations of *Arnica montana* might lose their resource value irreversibly (Minarchenko 2013).

In the Carpathian macroregion, natural areas protected at the national level have the status of national parks, protected landscape areas, or nature reserves. The majority are related to areas of cultural or primeval forests. Slovakia, Poland, and Romania nominate nature reserves. A similar term, nature "zapovidnyk," is designated in Ukraine; the national biosphere "zapovidnyk" (reserve) also occur. Forest and scientific reserves are also formed in Romania. Protected landscape areas are designated in Slovakia and Poland, nature parks in Romania, and landscape parks in Poland and Ukraine (Ptacek et al. 2011).

Over the half of the entire Carpathian area is under various forms of protection, thus only 3% of forests are completely excluded from logging, and the effectiveness of forest protection efforts varies. In recent decades, the effectiveness of protection (lowered deforestation and related disturbance) improved in Slovakia and Ukraine, whereas it is reduced in Romania. Broad areas of protected virgin and quasi-virgin forests with ongoing efforts toward a strict protection status (e.g., additional 12,288 ha of Ukrainian forests since 2018) might serve as study plots for sustainable forest investigation and practices (Kholiavchuk et al. 2024).

The following important medicinal plants are endangered and protected at the local or national levels in Ukraine: *Allium ursinum, Atropa belladonna, Colchicum autumnale, Gentiana lutea, Hedera helix, Inula helenium, Lycopodium annotinum, Lycopodium clavatum,* and *Rhodiola rosea.* The threats for these herbs are caused by felling, digging, grazing, eradication of whole plants, *etc*. The main actions aimed at their conservation in the Ukrainian Carpathian region comprise the ban on extraction or harvesting from the natural habitats, population monitoring, and promotion of natural regeneration, regulation of grazing, and reintroduction and cultivation. There is a need to enforce the protection actions and develop additional conservation and resource restoration measures regarding such species (Minarchenko 2013).

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