A Hidden Bio-Cultural Erosion? Mountain Marginalization and the Resilience of Traditional Environmental Knowledge Among Pomaks in the Greek-Bulgarian Rhodopes

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Abstract: Studying cross-cultural and cross-border plant use in fragile mountain areas is essential to understanding the factors that influence Traditional Ecological Knowledge (TEK). This study focuses on the Muslim Bulgarian-speaking Pomaks minority living along the Central Greek-Bulgarian border in the Rhodope Mountains. Fieldwork conducted in the summer of 2023 involved 62 semi-structured interviews documenting the traditional uses of wild foods, edible mushrooms, and medicinal plants. A total of 81 wild and cultivated taxa were recorded. The results revealed notable differences between the two countries: Pomak communities in Bulgaria reported significantly higher species diversity and a more even distribution of foraging knowledge across taxa compared to those in Greece ($\chi^2 = 6.33$, df = 2, $p = 0.042$). This disparity is linked to the ongoing engagement with natural landscapes in Bulgaria, while Greek Pomaks have faced marginalization, poverty, and outmigration, which disrupted traditional land-based practices such as shepherding and small-scale farming. These shifts have contributed to the erosion of TEK in Greek communities. The study highlights the importance of sustained interaction with the environment in preserving biocultural knowledge and points to the need for targeted efforts to support the revitalization of sustainable foraging practices, particularly in communities facing socioeconomic and cultural pressures that threaten the continuity of traditional plant knowledge.

Keywords: Bulgaria, Ethnobotany, Ethnomycology, Greece, Traditional ecological knowledge, Rhodopes, Pomaks, Wild food plants

Introduction

Traditional ecological knowledge (TEK) is vital for local communities' well-being and is a key element of cultural identity. TEK has been a focal point of research within the ethnobiological field, and considerable attention has recently been given to understanding the dynamics of such knowledge across state and cultural borders (Sulaiman et al. 2024a). One such interesting border area includes the Rhodope Mountains of the Balkan peninsula, which straddle the border between Bulgaria and Greece (Mincheva

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et al. 2023). Despite their ecological and cultural significance, these mountains remain relatively underexplored in scientific research, especially in ethnobotanical studies. Historically, wild plants have played a crucial role in local subsistence strategies, especially during periods of economic hardship and seasonal scarcity. Ethnobotanical studies conducted in the Rhodope Mountains have confirmed the continuity of such practices among local communities (Mincheva et al. 2023). In particular, wild greens, herbal teas, and mushrooms are still gathered and used today, both for household needs and traditional healthcare.

The Rhodope Mountains' shared ecological characteristics, including a Mediterranean-continental climate, diverse soil types, and varying altitudes, foster extraordinary biodiversity that supports the growth of numerous wild plant species (Nedelcheva and Dogan 2019; Pavlova et al. 2003; Tzonev et al. 2013). However, the sociocultural context of this region adds layers of complexity to the conservation and usage of ethnobotanical knowledge. The sociocultural landscape of the Rhodope Mountains is intricately shaped by the interactions of various ethnic groups, including Bulgarians, Turks, Albanians, and Pomaks (Muslim Slavs). The Ottoman period significantly influenced local governance, trade, and cultural exchanges, leaving a legacy of shared traditions and culinary practices. Despite this, political divisions following the Balkan Wars (1912–1913) and subsequent national policies have introduced varying degrees of socioeconomic development and cultural shifts between the Bulgarian and Greek sides of the Rhodope Mountains (Tahir 2012). Additionally, the internal migration of Muslim populations, particularly during the Communist period, along with the influx of mine workers from across Bulgaria, further shaped the region's demographic and cultural landscape, contributing to the exchange and transformation of local traditions, including those related to ethnobotanical knowledge. Whether ethnobotanical knowledge is conserved, adapted, or lost in regions with similar ecological features but distinct socio-political contexts is of central importance, as it highlights the influence of cultural, socioeconomic, and political factors affecting the resilience and change of biocultural heritage. In the Rhodope Mountains, for example, although the landscape and biodiversity are shared, how local communities interact with these resources can differ. These variations may be linked to cultural identity, economic practices, and external influences, such as state policies or modernization. Therefore, understanding the conservation, adaptation, or loss of ethnobotanical knowledge requires considering both ecological and sociopolitical dimensions (Kouli 2020; Masci et al. 2024).

However, different sociocultural dynamics and national policies may have uniquely shaped ethnobotanical traditions (Daskalova et al. 2010; Mincheva et al. 2019). For instance, economic migration has partially caused the abandonment of traditional farming practices, favoring modern agricultural methods or convenience foods (Johns et al. 2013). Conversely, the resurgence of interest in organic and "local" foods might contribute to the revival or adaptation of traditional plant knowledge (Muller 2018). This highlights the need to understand the complexities of local life and intercultural variations in TEK. Although some taxonomic and environmental studies have focused on specific groups such as butterflies and birds, investigations into the traditional ecological knowledge and plant use of local communities are notably sparse (Tsioutsiou et al. 2019). Additionally, historical investigations have often been fragmented, with findings scattered across various articles that rarely focus directly on ethnobotany.

This study explored wild foods and medicinal foraging traditions among one of the main cultural groups of the Rhodope Mountains: The Pomaks. Communities from this group have existed on both sides of the Rhodope border, a border that in its present placement has existed for roughly one century. By comparing ethnobotanical practices among Pomaks in Bulgaria and Greece, this research seeks to uncover patterns of shared cultural heritage, regional variation in plant use, and the influence of ecological and historical factors. Furthermore, it highlights how marginalization, migration, and socioeconomic challenges have shaped these practices. By documenting the ethnobotanical knowledge of these communities, this research contributes to preserving the intangible cultural heritage and human ecology of the Rhodope Mountains region. The findings also underscore the significance of the resilience of local knowledge about

(wild) plants as a critical resource for sustainable livelihoods in a rapidly changing world.

Methodology

In this study, plant species were categorized based on their degree of human management into two main groups: wild and semi-domesticated. This classification follows previous ethnobotanical frameworks (Menéndez-Baceta et al. 2012; Pieroni et al. 2022). Wild plants refer to species that grow spontaneously in natural habitats without deliberate human intervention, such as *Urtica dioica* L. and *Thymus vulgaris* L., commonly gathered from meadows, forests, and roadsides.

Semi-domesticated plants are those that are not actively cultivated but are tolerated, protected, or occasionally managed within the local landscape. These may include species like *Sambucus nigra* L. and *Juglans regia* L., which are spared during land clearing or pruned occasionally, reflecting traditional low-input practices. This group also includes formerly cultivated species that have naturalized and continue to be used locally. Semi-structured interviews exclusively addressed the local uses of wild and semi-domesticated plants.

Study Area and Historical Background

The Pomak communities of the Rhodope Mountains, which stretch across southern Bulgaria and northern Greece, have preserved traditions shaped by centuries of isolation, transhumant pastoralism, and subsistence farming. As Muslim Slavic groups, they possess a rich ethnobotanical heritage, especially in the use of wild plants for herbal teas, food, and medicinal purposes, all intricately linked to seasonal cycles and religious customs (Ivancheva and Stantcheva 2000). Historically, the Pomaks have been identified either as Muslim Bulgarians or as a distinct ethnic group, depending on the socio-political context (Markou 2020; Nikolov 2019). These complex identities play a key role in understanding the conservation and application of ethnobotanical knowledge in the region, as each group has uniquely contributed to its cultural and ecological landscape.

Their livelihood activities typically include small-scale agriculture, animal husbandry (especially sheep and goats), and the foraging of wild plants, mushrooms, and forest products. Women's roles in gathering and preparing herbal remedies are especially significant, reflecting a strong oral tradition and gendered transmission of knowledge. These communities represent a unique biocultural system where ecological knowledge, cultural identity, and adaptation to mountainous landscapes are intimately intertwined.

The Western Rhodopes Mountain forms the most prominent mountain group within the Rilo-Rhodopean massif, spanning a total area of 11,220 km^2, with 8,732 km^2 located in Bulgaria and 2,488 km^2 in Greece (Fig. 1) (Beron 2006; Petrov and Helversen 2011). The elevation in the region varies significantly, with the foothills starting at approximately 70–100 m in Greece. At the same time, the highest peak, Golyam Perelik Summit in Bulgaria, rises to 2,191 m above sea level (Bulgarian Geographic Institute, 2023). The average elevation across the mountain range is 1,098 m (National Geographic Society, 2024). A portion of the landscape, around 51.9%, consists of submontane terrain (1,000–1,600 m), and 8.7% is classified as montane land (above 1,600 m) (Beron 2006; Petrov and Helversen 2011). The area experiences maximum precipitation in May and June, with a secondary peak in November and December, and its river network reflects the local precipitation patterns. The climate is transitional continental, with average annual temperatures ranging from 5 to 9 °C (Britannica 2023; Schuler et al. 2004). Vegetation distribution is influenced by altitude and slope exposure, with coniferous species such as *Pinus sylvestris* L., *Pinusheldreichii* H.Christ, *Picea abies* (L.) H.Karst., and *Abies alba* Mill. dominating between 1,000 and 1,900 m in Bulgaria, covering over 70% of the forested areas. At lower altitudes, the vegetation primarily consists of *Fagus sylvatica* L., *Quercus petraea* (Matt.) Liebl., *Quercus pubescens* Willd., *Quercus frainetto* Ten., *Quercus cerris* L., *Juniperus oxycedrus* L., and *Juniperus excelsa var. excelsa*.

These mountain areas have a rich historical background, with industries such as textiles, tobacco

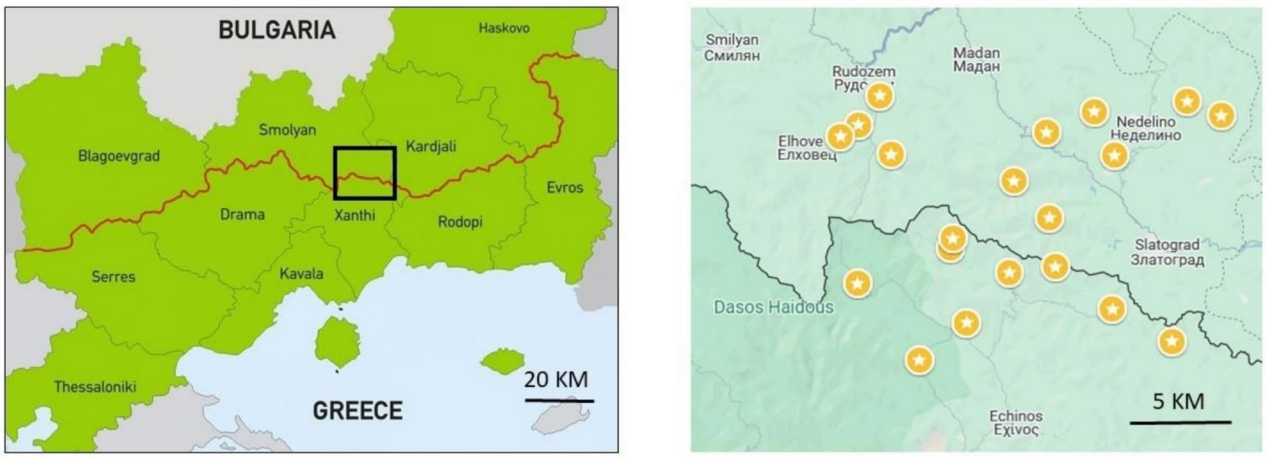

Fig. 1. Map of the study area and visited villages in the border region between Bulgaria and Greece

processing, and small-scale manufacturing playing a key role. Additionally, the timber and mining industries, along with stock animal farming and the region's status as the largest potato production area, have significantly influenced the local economy and landscape. However, economic development in the region remains uneven, with rural areas often struggling with high unemployment rates, particularly among the youth, and marked disparities in wealth compared to urban centers. Despite these challenges, the region plays a significant role in Southeast Europe's cultural and ecological landscape (Kouli 2020). The Rhodope Mountains have historically served as a crossroads of civilizations, fostering interactions among Bulgarians, Greeks, Pomaks, and other ethnic groups. This diversity has enriched the region's cultural traditions but has also been a source of tension during political upheavals. The coexistence of Christian Orthodox and Muslim communities is a defining feature of the area's cultural mosaic, reflecting a legacy of Ottoman rule and subsequent national movements (Valtchinova 2019a, b).

Prior to the Balkan Wars, the Rhodope Mountains functioned as a cohesive cultural and ecological region, with diverse populations including Bulgarians, Pomaks, Turks, and others interacting fluidly across what would later become national borders. The post-1913 division between Bulgaria and Greece disrupted these long-standing ties and triggered population displacements, particularly affecting Muslim communities, which redefined local identities and altered access to land and resources (Nikolov 2019). In the ensuing decades, diverging political and economic paths, socialist collectivization, and internal resettlements in Bulgaria versus market-oriented rural development in Greece further transformed land use, infrastructure, and cultural continuity. These transitions significantly impacted the transmission, adaptation, or erosion of TEK across the borderland (Troeva and Hristov 2017; Valtchinova 2019a, b).

Data Collection

The data for this study were collected during a field survey conducted in July 2023 across 18 localities (Fig. 1). The study locations were selected for detailed analysis based on their linguistic, anthropological, and economic characteristics (Table 1) within the Rhodope Mountains, spanning the Bulgarian and Greek border regions. The selection of sites aimed to capture diverse ecological and cultural settings, emphasizing rural villages that are more remote and known for their attachment to agro-forestry-pastoral activities.

Ethnobotanical data were gathered through semi-structured interviews with local inhabitants, focusing on individuals with knowledge of traditional practices, including elderly residents and those engaged in agriculture or herbal use. Interviews were conducted with 62 participants: 31 women (11 Greek nationals from Greek villages and 20 Bulgarian nationals from Bulgarian villages) and 31 men (6 Greek nationals and 25 Bulgarian nationals) across 12 villages in Bulgaria and 6 villages in Greece. The terms Greek and Bulgarian here denote nationality and country of residence, not ethnicity. The majority of informants were elderly individuals (60 to 85 years old), with some younger participants (30 to 55 years) also involved. While no mean age was calculated, participants generally represented an older demographic. Education levels varied, ranging from individuals with no formal education to those who had completed high school. Most participants were engaged in farming activities, while a smaller portion were employed in other local sectors.

The questions explored the collection, preparation, and use (consumption) of wild and semi-domesticated food plants, mushrooms, aromatic and medicinal plants, as well as cultural and ecological insights related to the local flora.

The interviews were conducted primarily in Bulgarian or Greek, depending on the participants' language preference. However, many participants, especially the older generations, spoke the local Rup (Rhodopski) dialect, which is a unique blend of Slavic, Greek, Turkic, and regionally rooted lexical elements. For cases where local dialects were used, translation or interpretation was provided by local collaborators who were fluent in these dialects. The complexity of the linguistic landscape is noted, with dialects reflecting the region's diverse historical and cultural influences.

A near-equal gender distribution among participants provided a comprehensive perspective on traditional practices. Female participants often shared knowledge of domestic

Table 1. Characteristics of the villages visited, and the sample considered.

Visited villages	Participants gender		Language	Socio-anthropological characteristics	Vegetation and landscape	Main economic activities	Elevation (m)
	Female	Male					
Bulgaria							
Аламовци [Alamovtsi] (BG)	–	5	Bulgarian	Community-oriented, rural population	Densely forested mountain terrain	Small-scale farming, local trade	650–750
Дуня [Dunya] (BG)	2	1	Bulgarian	Predominantly agricultural, small rural group	Mixed forest and open meadows	Subsistence agriculture, minor trade	500–600
Изгрев [Izgrev] (BG)	2	1	Bulgarian	Agrarian-focused	Semi-forested hills, grazing lands	Pastoralism, subsistence farming	600–700
Козарка [Kozarka] (BG)	–	2	Bulgarian	Rural and traditional family structure	Rugged forested areas	Wild plant gathering, subsistence farming	700–800
Цацаровци [Tsatsarovtsi] (BG)	1	1	Bulgarian	Rural family-based community	Mixed agricultural and forested areas	Small-scale farming, subsistence crops	500–600
Старцево [Startsevo] (BG)	3	1	Bulgarian	Small-town, industrial influence	Open fields and mixed forests	Mining, small-scale local industries	500–600
Еленка [Elenka] (BG)	1	–	Bulgarian	Family-centered, agricultural lifestyle	Rugged forested landscapes	Wild plant gathering, pastoral activities	700–800
Долен [Dolen] (BG)	5	–	Bulgarian	Preservation of local traditions	Mountains with diverse vegetation	Agro-tourism, small-scale farming	900–1,100
Рудозем [Rudozem] (BG)	5	–	Bulgarian	Industrialized, small-town dynamics	Mixed forests and open agricultural zones	Mining, small-scale industrial work	800–1,000
Оглед [Ogled] (BG)	1	2	Bulgarian	Small rural family-based community	Forested hills with meadow areas	Subsistence agriculture, livestock farming	500–600
Рибница [Ribnitsa] (BG)	–	4	Bulgarian	Agrarian and tightly-knit rural population	Semi-forested mountain terrain	Pastoralism, wild herb gathering	600–700
Ерма Река [Erma Reka] (BG)	–	8	Bulgarian	Community-centered, culturally preserved	Rugged, forested valleys and riverbanks	Small-scale agriculture, eco-tourism	700–800
Greece							
Pleteno Koinsep/ Κοιν.Σ.Επ. (GR)	1	–	Bulgarian and Greek	Cooperative-based, entrepreneurial focus	Forests and terraced agricultural lands	Cooperative farming, crafts, eco-tourism	600–700
Dimario (GR)	2	1	Bulgarian and Greek	Cooperative-focused rural group	Meadows and semi-forested areas	Agriculture, subsistence farming	500–600
Medousa/Μέδουσα (GR)	3	–	Bulgarian and Greek	Isolated, culturally resilient community	Diverse Mediterranean and forest flora	Herbal production, subsistence farming	600–700
Katani/Κοττάνη (GR)	1	1	Bulgarian and Greek	Matrifocal with clan traditions	Forested mountainous slopes	Agro-pastoral activities, artisanal crafts	900–1,100
Κίδαρις/Kidaris/ Кидарис/Сареле, Саръер (GR)	–	3	Bulgarian and Greek	Matrifocal influence	Rocky terrain, Mediterranean shrubs	Subsistence farming, pastoral activities	400–600
Ano Thermes/Θέρμες (GR)	4	1	Bulgarian, Greek, and Turkish	Mixed ethnolinguistic community	Hot springs, sparse Mediterranean flora	Tourism (thermal springs), agriculture	700–900

preparations, while male participants contributed insights into plant collection and ecological practices. We have to recognize that thematic saturation was reached relatively early during fieldwork in both the Bulgarian and Greek study areas. In both contexts, recurrent patterns in plant and fungal uses, local names, and preparation methods emerged consistently during interviews and observations. This indicated that further data collection was unlikely to generate substantially new information, thereby strengthening the reliability of the findings within each region. Species identification in this study was based on a combination of field collection, expert consultation, and reference to regional botanical literature. Voucher specimens of the plant material collected during the fieldwork were deposited in the Ethnobotanical Voucher Collection of the Laboratory of Pharmacognosy at Sofia University. Identification of these specimens was performed by Prof. Aneli Nedelcheva (Sofia University) using standard regional botanical keys and floras (Delipavlov and Cheshmedzhiev 2011; Strid and Tan 2002).

For taxa mentioned by participants but not collected during this study (e.g., due to seasonality or conservation concerns), identification was based on a triangulation approach: (1) local folk names and detailed descriptions provided by informants, (2) field photographs taken during interviews and walks, and (3) cross-referencing with previously collected specimens and herbarium materials available at Sofia University. All identifications were further verified against established taxonomic databases, the Plant List (2013), and Euro + Med PlantBase (https://europlusmed.org/) to ensure accuracy and consistency in nomenclature.

The study adhered to the International Society of Ethnobiology (ISE) Code of Ethics (ISE 2008). Prior to conducting interviews, informed consent was obtained from all participants. Participants were fully briefed on the purpose of the research, the methods used, and their rights, including the voluntary nature of participation and the option to withdraw at any time without consequence.

No personal or identifying information was collected, and data were anonymized to ensure confidentiality. The research team maintained respectful engagement with local communities and emphasized reciprocity through knowledge sharing and feedback sessions where possible. Formal ethics approval was not required under the regulations of the institutions involved; however, the study was conducted in accordance with widely accepted ethical standards for field research in ethnobotany.

In addition to interviews, observational data were recorded on the surrounding landscapes, focusing on the habitat types where plants were collected. This contextual information supports the analysis of plant distribution and cultural preferences in the region.

Botanical and Mycological Identification and Data Analysis

In the Rhodope Mountains, a region straddling the border between Greece and Bulgaria, plant and fungal specimens were systematically collected from several villages to explore local communities' ethnobotanical and mycological knowledge. Species identification was conducted using regional botanical keys, such as Flora Europaea (Tutin et al. 1964), and further verified through consultation with local experts and herbarium collections. We referred the current quoted plants to the voucher specimens that were collected during a previous field study in a contiguous area (Pieroni et al. 2014). Fungal identification relied on spore morphology and substrate characteristics, cross-referenced with expert knowledge. Field data included local names, parts used, traditional preparation methods, and ecological factors associated with the species. The analysis was divided by country (Bulgaria and Greece), and a cluster analysis was performed to group species according to their geographic distribution in these areas, highlighting both shared and region-specific usage. We performed a Chi-square test of independence to assess whether the distribution of wild plant taxa across three citation frequency categories ($< 10\%$, 10–40%, $> 40\%$ of participants, respectively) differed significantly between the two countries. The analysis was based on the number of taxa from Bulgaria and from Greece with clear frequency assignments. Expected frequencies were checked to ensure that the assumptions of the Chi-square test were met. Additionally, a Venn diagram was created to illustrate the most frequently cited species across both countries, emphasizing those plants that were commonly used in both regions and those that were unique to one. The results were

compared with the most extensive ethnobotanical datasets of the Balkan mountains, such as those presented in the work of Pieroni and Quave (2006), as well as the references contained therein, which provide broader insights into plant usage and cultural practices across the region; other more recent sources were also employed by searching Scopus using the keywords "ethnobotany" and each single Balkan country name. We indeed found that the number of ethnobotanical studies specifically focused on Bulgaria and Greece was relatively low compared to other regions of the Balkan Mountains. This could be due to several factors, including the limited scope of previous studies, regional research gaps, and the relatively recent interest in ethnobotany in these countries. The data analysis was performed using SAS 9.4, which provided clustering and frequency analysis, while Microsoft Excel was used to visualize the Venn diagram.

Results

Documenting Plant and Fungal Foraging Practices

These mountain areas, characterized by diverse landscapes ranging from fertile plains to rugged mountain terrain, host various plant species integral to local communities' cultural and medicinal practices. Indigenous and mixed populations in this region, including Bulgarians, Greeks, and others, have long utilized these plants for various purposes, from medicinal to culinary uses.

The data presented in Electronic Supplemental Material (ESM 1) highlights the distribution of plant families within the Rhodope Mountains in the border regions between Bulgaria and Greece. The most represented families are Amaranthaceae, Asteraceae, and Cantharellaceae. The Amaranthaceae family is the most prominent, with three species identified in the study (*Atriplex hortensis* L., *Amaranthus retroflexus* L., and *Chenopodium album* L.). The Asteraceae and Cantharellaceae families are each represented by two species (*Achillea millefolium* L., *Cichorium intybus* L., and *Cantharellus cornucopioides* Pers., *Cantharellus cibarius* Fr., respectively).

The wild plants in these regions are uniquely adapted to the area's varying climatic and ecological conditions. Higher elevation zones, with their cooler climates and rocky soil, support species such as *Sideritis scardica* Griseb. and *Thymus vulgaris*, known for its medicinal properties. These plants thrive in harsh mountain conditions and are often harvested for their therapeutic value, such as their ability to treat respiratory issues, digestive problems, and inflammation (Table ESM 1).

Wild plants are equally diverse in lower elevation areas, with species such as *Achillea millefolium*, *Urtica dioica*, and *Cichorium intybus* being commonly foraged and domestically used. These plants are collected for various purposes, including remedies for pain, fever, and digestive disorders. *Achillea millefolium*, for example, has long been valued for its ability to help heal wounds and regulate menstrual cycles.

Our findings show that several species of the 59 wild plants and mushrooms documented are particularly notable for their traditional regional use. The plants identified include species such as *Amaranthus retroflexus*, *Chenopodium album*, *Crataegus monogyna* Jacq., *Achillea millefolium*, *Cichorium intybus*, *Salvia verticillata* L., *Satureja montana* L., *Sambucus ebulus* L., and *Sonchus oleraceus* L., among others. These plants are used in various forms, including for medicinal purposes, as food additives, or in traditional rituals.

In addition to the plant species, a number of fungal species were also found to play a key role in the ethnobotanical knowledge of the region. These include *Paliurus spina-christi* Mill., *Agaricus arvensis* Schaeff, and *Amanita caesarea* (Scop.) Pers., which are valued for their edibility or medicinal properties in the local cultures.

Additionally, seven cultivable species were recorded, including *Atriplex hortensis*, *Phaseolus vulgaris* L., *Vitis vinifera* L., *Lactuca sativa* L., *Cucumis melo* L., *Cucurbita pepo* L., and *Cucurbita maxima* Duchesne. These cultivable species grow within the region and contribute to the local communities'agricultural diversity and food security.

Furthermore, the study identified 14 species that are considered semi-domesticated (SD) or commonly cultivated in the region, reflecting the integration of wild and domesticated plants into local farming systems. These species include *Prunus avium* (L.) L., *Ribes nigrum* L., *Ribes uva-crispa* L., *Pyrus communis* L., *Tilia* spp.,

Crataegus germanica (L.) Kuntze, *Juglans regia*, *Prunus domestica* L., *Ficus carica* L., and *Malus domestica* (Suckow) Borkh., which are typically cultivated or domesticated within local farming systems. *Cydonia oblonga* Mill. (Quince) and *Trigonella foenum-graecum* L., which are species introduced and commonly found in local gardens or orchards. *Mentha spicata* L. and *Rumex patientia* L. are used as garden herbs and semi-domesticated food plants. *Rumex patientia* serves as a key example of a plant with a dynamic status in local agroecological systems. While it is widely cultivated as a food plant across Bulgaria and other parts of Europe, in some contexts it grows spontaneously or is maintained with minimal care, reflecting a semi-cultivated status. Similarly, *Helianthus tuberosus* L. is a species that has escaped from cultivation and now grows independently, without being fully domesticated. These examples illustrate the blurred boundaries between wild, semi-domesticated, and cultivated categories, emphasizing the evolving nature of human-plant relationships in the region.

Wild Foods and Medicinal Plants and Mushrooms in the Rhodope Mountains

The study identified a range of wild plants that have been traditionally used for food and medicinal purposes in the Rhodope Mountains, as illustrated in Fig. 2. Notable examples include very uncommon food and herbal uses of *Capsella bursa-pastoris* Medik., *Clematis vitalba* L., *Hedera helix* L., *Paliurus spina-christi*, *Helianthus annuus* L., *Lactuca serriola* L., *Onopordum acanthium* L., *Salvia officinalis* L., and *Trigonella foenum-graecum*. While some of these plants, such as *Helianthus* spp., have widespread uses globally, in our study area, their specific uses differ and hold particular local significance that is less commonly documented in broader ethnobotanical literature. Therefore, although not uncommon globally, their local applications in this region contribute unique insights into the cultural heritage and plant use practices, particularly about wild or semi-domesticated species. A few documented uses are rare or, to our knowledge, have never been reported in contemporary European foraging, such as using *Hedera helix* and *Helianthus tuberosus* leaves as food. *Sideritis scardica* (Fig. 2a) and *Origanum vulgare* L. (Fig. 2b) are commonly found in Bulgaria, while another sub-species of *O. vulgare* (Fig. 2c) is prevalent in Greece. These species hold significant importance in the region due to their medicinal and culinary uses, especially in herbal teas. *Sideritis scardica* is well recognized in Bulgarian ethnobotanical traditions for its role in local remedies, while *Origanum vulgare* and its subspecies have widespread culinary and medicinal applications across the Balkans, including Greece. The differences in subspecies between Bulgaria and Greece further highlight the region's ecological diversity and the rich traditional knowledge associated with these plants.

These plants and others, such as *Zea mays* L., *Triticum aestivum* L. (commonly used in the form of bulgur), and *Atriplex hortensis*, are integral to the local food and herbal traditions, used in both fresh and dried forms. Over time, however, the methods of using and preparing these plants have evolved. While certain plants, such as wild berries, have circulated within communities with varying intensity levels, how these plants are prepared and consumed has shifted. Among the plants used in the past, some continue to hold cultural significance, while others have declined. For example, dried fruits ("shushulki") and dried mushrooms, along with herbal teas like *Thymus serpyllum* L. and *Matricaria chamomilla* L. (Fig. 3), remain fundamental pillars in Bulgarian herbal domestic practices. While the use of some herbal teas has declined at present, the collection and trade of wild mushrooms continue to be a vital cultural and economic activity.

In some Bulgarian Pomak communities, protective amulets (Fig. 3d) are traditionally made using *Artemisia absinthium* L., a plant believed to have the ability to ward off evil influence or bad luck. These amulets are typically worn or placed near infants to ward off the "evil eye" or bad spirits. Although not widely cited in interviews, their presence reflects a deeper layer of ethnomedicinal belief systems and symbolic plant use in the region.

Intercultural Comparison of Plant and Fungal Foraging Practices in the Rhodope Mountains

The plants and fungi used in the Rhodope` Mountains exhibit diverse culinary,

Fig. 2. Photos of some plants that were recorded in the study area: **a** *Sideritis scardica* (Kidari village), **b** *Origanum vulgare* (Alamovtsi village), **c** *Origanum vulgare* (Kottani village)

Fig. 3. Examples of wild food plants, mushrooms, and medicinal remedies that are traditionally used among Bulgarian Pomaks: **a** dried fruits of apples and rose hips for preparing *oshaf*; **b** dried *Boletus* spp.; **c** herbal tea made by *Thymus serpyllum* and *Matricaria chamomilla*; **d** protective amulet (Tsatsarovtsi village)

medicinal, and cultural applications, as detailed in Table ESM 1. Leaves are the most frequently used parts (40%), commonly prepared as herbal teas or cooked as vegetables, e.g., *Centaurium erythraea* Rafn (tea for colds and heart issues), *Cichorium intybus* (tea for diarrhoea), and *Mentha spicata* (tea for stomach pain). Flowers and inflorescences (11%) are primarily used in teas, jams, syrups, and *rakia*, with notable examples including *Achillea millefolium*, *Hypericum perforatum* L., *Robinia pseudoacacia* L., and *Rosa canina* L. Fruits (24%) such as *Prunus avium*, *Malus domestica*, and *Cornus mas* L. are consumed fresh, dried, or transformed into jams, syrups, or wine. Fruiting bodies of fungi (16%), including *Agaricus arvensis* Schaeff. and *Cantharellus cibarius*, are cooked, fried, or preserved for later use. Seeds (5%) from plants like *Corylus avellana* L. and *Cucurbita pepo* are eaten as snacks or used in traditional desserts (Fig. 4).

In Bulgaria, 29.3% of the recorded wild plants and fungi were cited by fewer than 10% of participants, falling into the low citation frequency category. Further, 31.7% were cited by 10–40% of participants (moderate frequency), and 26.8% were cited by more than 40% of participants (high frequency). This indicates a relatively balanced distribution of taxa across the three citation categories, with a slight emphasis on those in the low and moderate frequency groups (Fig. 5).

In contrast, on the Greek side of the border, the low citation frequency category includes the highest proportion of taxa, with 60.9% of the recorded plants and fungi cited by fewer than 10% of participants. The moderate frequency category includes 17.4%, while only 21.3% fall into the high citation frequency category. This pattern suggests that in Greece, a larger share of wild taxa is known or remembered by fewer individuals, indicating a more fragmented or diffuse distribution of plant knowledge among participants.

These results highlight different patterns in the frequency of citation in Bulgaria and Greece. Bulgaria exhibits a more even distribution across the frequency categories, whereas Greece displays a higher concentration of plants with low frequencies and fewer plants in the high-frequency category.

A Chi-square test comparing the distribution of plant taxa by citation frequency categories between Bulgarian and Greek Pomak communities revealed a statistically significant difference ($\chi^2 = 6.33$, $df = 2$, $p = 0.042$). These results confirm that knowledge in Bulgaria is more evenly distributed across plant taxa. At the same time, in Greece, it is more fragmented, with a higher concentration of plants known only by a few individuals.

This pattern may, at least in part, reflect the lower number of participants interviewed in Greece compared to Bulgaria. A smaller sample size tends to yield a broader but less repetitive set of citations, potentially inflating the number of low-frequency entries and reducing the likelihood of multiple independent mentions of the same plant species.

The ethnobotanical analysis of top-quoted plant taxa across Bulgaria and Greece reveals 26 prominent species (Fig. 6), displaying distinct regional preferences alongside shared cultural practices.

Greece has six unique taxa: *Cornus mas*, *Malus domestica*, *Origanum vulgare*, *Prunus domestica*, *Urtica dioica*, and *Vitis vinifera*. These plants are integral to Greek traditions, with *Cornus mas* and *Prunus domestica* valued for their fruits in preserves and culinary dishes, *Origanum vulgare* as a culinary herb, and *Urtica dioica* widely used in medicinal and dietary contexts.

In contrast, Bulgaria demonstrates more diversity with 12 unique taxa: *Cydonia oblonga*, *Pyrus communis*, *Rubus fruticosus* L., *Mentha spicata*, *Ficus carica*, *Amaranthus retroflexus*, *Salvia verticillata*, *Rubus idaeus* L., *Portulaca oleracea* L., *Rosa canina*, *Fragaria vesca* L., and *Rumex patientia.* These plants serve various purposes, from *Cydonia oblonga* and *Pyrus communis* prized for their fruits to *Mentha spicata* and *Salvia verticillata* for teas and medicinal applications, reflecting Bulgaria's rich ethnobotanical tradition.

Eight taxa are commonly quoted in both regions, highlighting their widespread cultural significance: *Phaseolus vulgaris, Helianthus tuberosus*, *Juglans regia*, *Amanita caesarea*, *Chenopodium album*, *Boletus edulis* Bull., *Pinus* spp., and *Robinia pseudoacacia*. For instance, *Amanita caesarea* (Scop.) Pers. and *Boletus edulis* are highly esteemed edible mushrooms, and

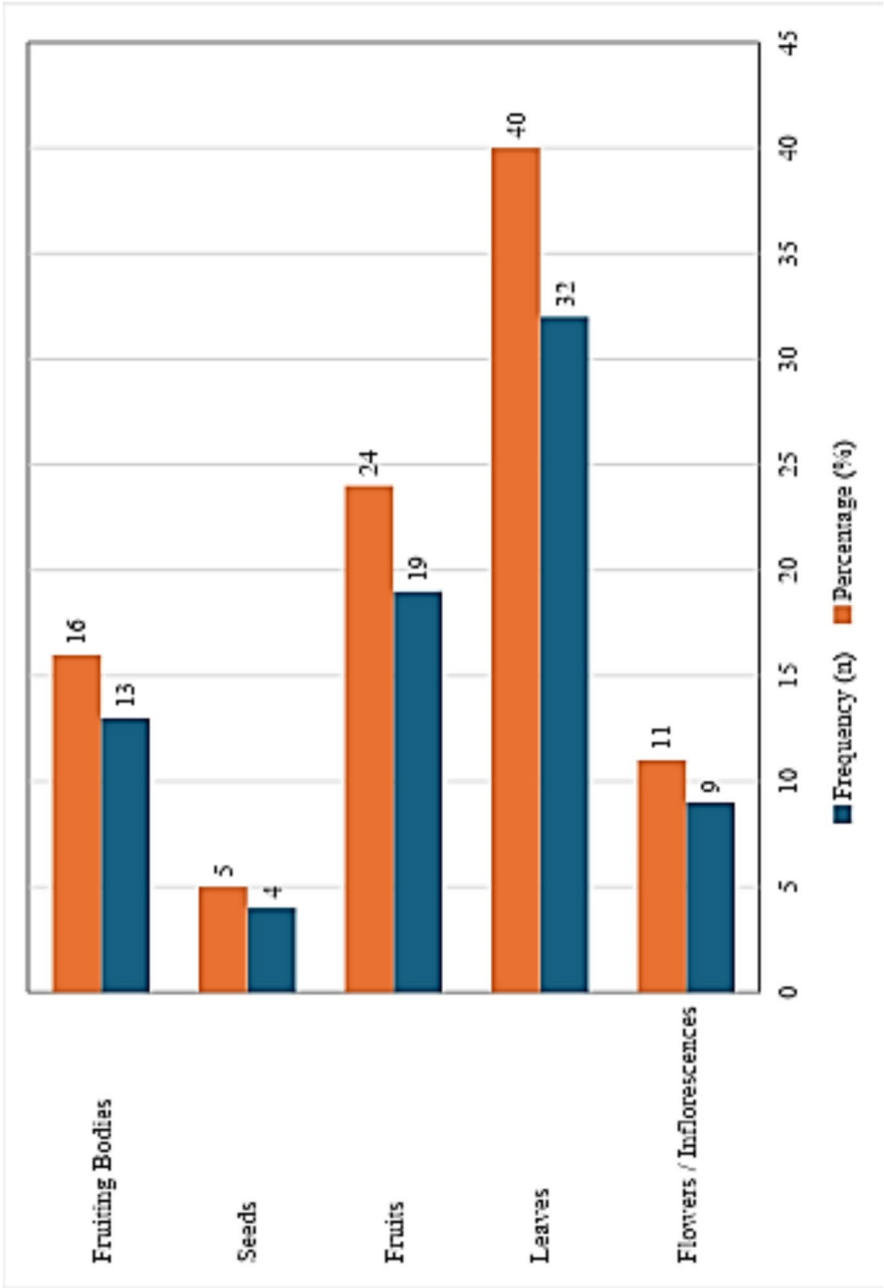

Fig. 4. Categorization of plant and fungi parts used for food, medicine, and other purposes

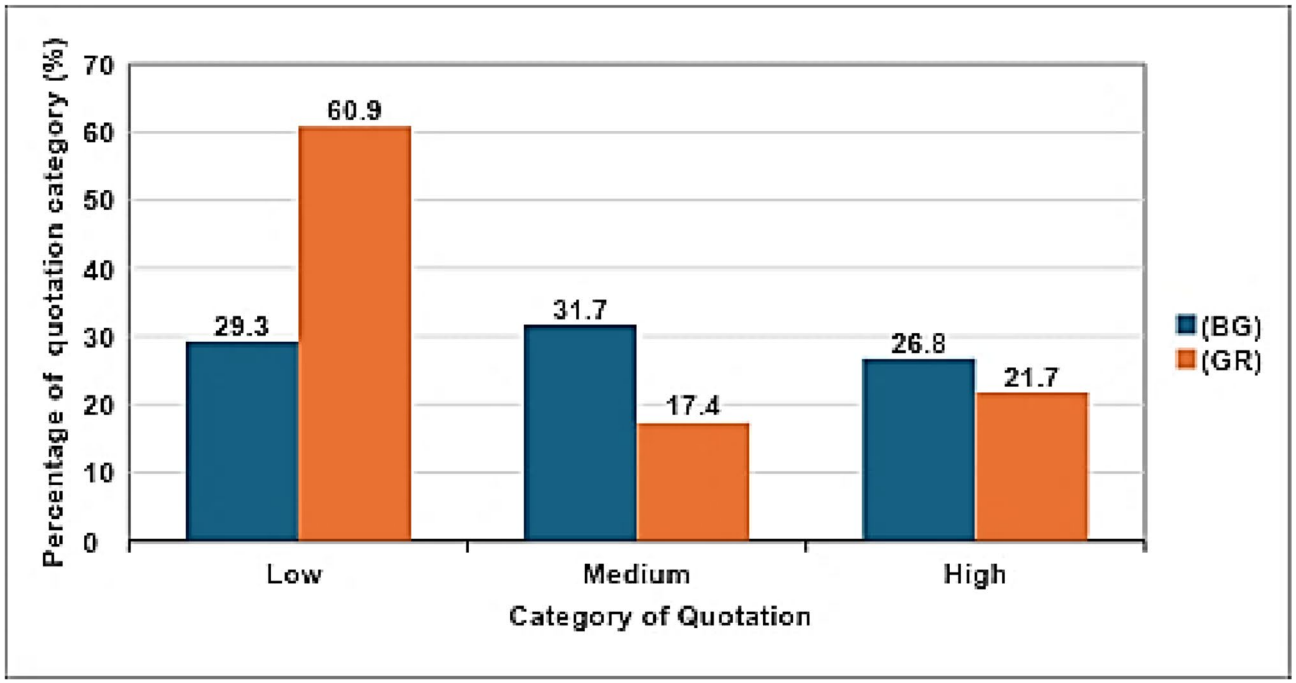

Fig. 5. Distribution of wild plant taxa by citation frequency among participants in the Bulgarian–Greek border region. Frequency categories represent the proportion of study participants who mentioned a given taxon in each region: low citation frequency (taxon cited by < 10% of participants); moderate citation frequency (taxon cited by 10–40% of participants); high citation frequency (taxon cited by > 40% of participants); (BG) = Bulgarian side; (GR) = Greek side of the border

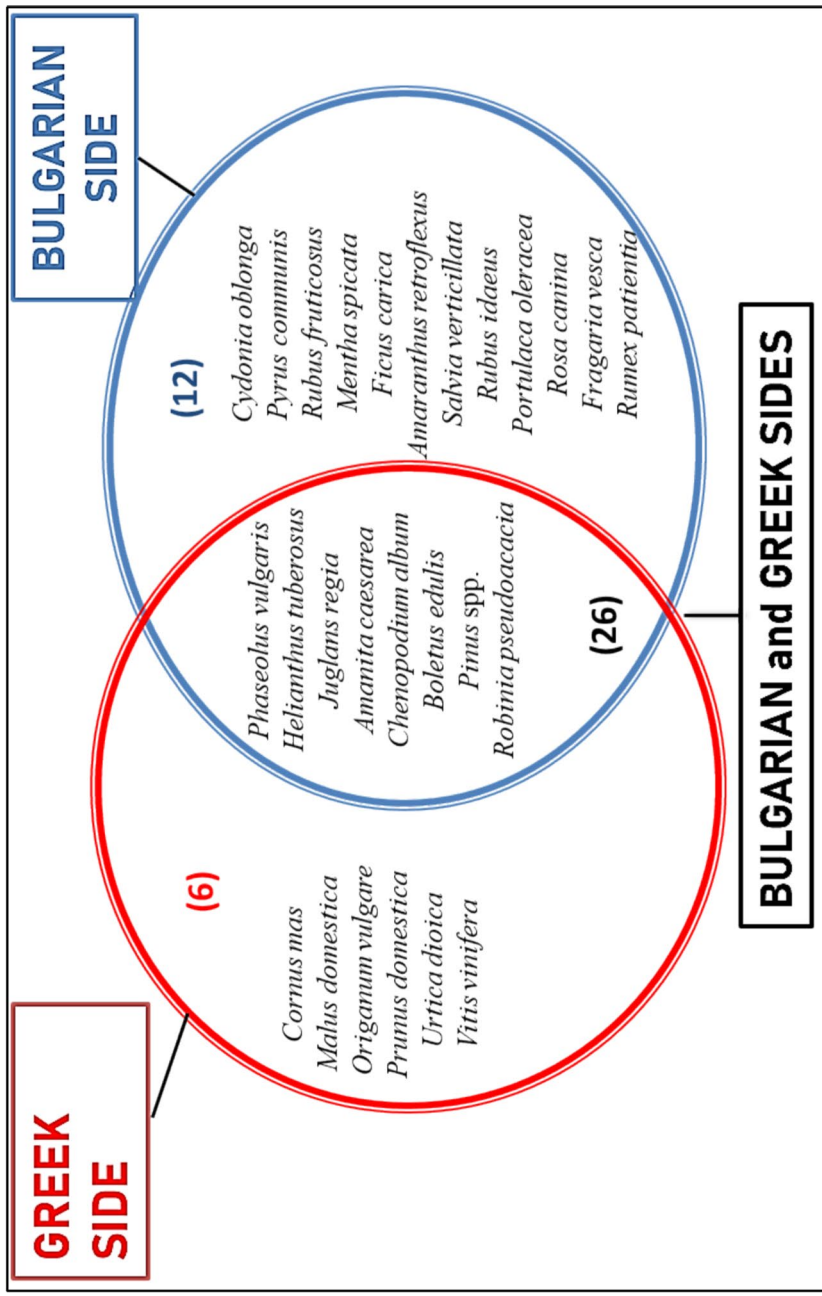

Fig. 6. Venn diagram comparing the Greek and Bulgarian border sides for the top-quoted genera as reported by the interviewees

Juglans regia is used for its versatile applications in food and medicine.

Discussion

The findings of this study provide insights into the human ecology and biodiversity of foraging practices within the social and cultural lives of communities in the Rhodope Mountains. This research could be one of the few papers to systematically report data on the traditional use of wild plants in this region, offering a unique contribution to understanding ethnobotanical and ethnomycological practices in the cross-border areas of Bulgaria and Greece. Various ecological, cultural, and socioeconomic factors influence quoted plants' frequency, use, and preference for traditional preparations (Daskalova et al. 2010). Additionally, migration, language decline, and the historically entangled transmission of intercultural or hybrid ethnobotanical knowledge, resulting from long-term interactions among diverse communities, are significant themes warranting exploration (Pieroni et al. 2017; Prakofjewa et al. 2023; Sõukand and Pieroni 2016; Troeva and Hristov 2017; Valtchinova 2019b). The diversity of plant uses documented across the Rhodope Mountains reflects the unique socio-ecological conditions of the region, which support both a rich variety of plant taxa and a deeply rooted cultural heritage. Bulgarian communities reported a higher number of wild taxa compared to Greek communities; a pattern likely influenced by cultural practices that foster sustained interaction with the natural environment. These include small-scale farming, foraging, and robust intergenerational transmission of Traditional Ecological Knowledge (Ivanova and Krastev 2023; Łuczaj and Dolina 2015).

While several ethnobotanical studies have focused on various parts of Bulgaria or Greece individually (Nedelcheva 2019), comprehensive, comparative research across the transboundary Rhodope region remains scarce. However, marginalization, poverty, and migration have contributed to the erosion of these practices among Greek Muslim communities, who were often excluded from a sense of national belonging due to stigmas associated with their religious identity. Middle-aged and younger generations of Greek Pomaks often relocated to urban centers in Turkey and Central Europe, leaving rural traditions behind, while the few remaining inhabitants started to rely mainly on remittances. In some cases, they even radicalized to strict Sunni Islam streams and also "Turkicised" their language. In one Greek village, for example, our interviews became problematic since the local Pomaks expressed their bitter anger for Greeks, Bulgarians, and all "foreigners" because of the long-standing marginalization and racism they felt as "second-class citizens" during the previous decades; they noted having been left alone in poverty due to their religious and linguistic differences from the Greek nation broadly, and as a result did not wish to integrate into mainstream Greek culture. Greek Pomaks framed this marginalization very often with the phrase "They have always considered us as Gypsies (by original translation)." The successive outmigration of Greek Pomaks over the past decades led to the loss of many small-scale farming practices tied to their reduction of deep understanding and awareness of their local natural world, and fewer plants and mushrooms being used. A few villages saw great reductions in population, while some others were completely abandoned.

Conversely, in Bulgaria, where some outmigration also occurred after the fall of communism during the past three decades, a much more harmonious social integration into the Bulgarian mainstream society occurred. Despite social and economic challenges, the persistence of traditional farming activities has helped maintain local knowledge and use of wild plants and mushrooms as affordable food and home medicine. Similar to ecological phenomena where the loss of species diversity appears delayed due to stored resources, the decline in TEK may not be immediately apparent as it is often preserved through the memories of older generations (Pieroni et al. 2022). However, in the context of the practical use of plants, it is not the plants themselves that are disappearing, but rather the knowledge and continuous ties associated with them. Therefore, we propose using the "hidden ecological erosion" framework to describe the slow, often unnoticed loss of traditional ecological knowledge (TEK) and sustainable plant use in the region. This concept highlights how social and cultural pressures gradually erode

community practices and knowledge. It helps emphasize the need to document and support these local traditions before they disappear.

The decline of the Pomak minority and its Bulgarian language variety in the Greek Rhodope Mountains also poses challenges to preserving ethnobotanical knowledge (Valtchinova 2019a, b). Local plant names and associated cultural narratives, which are deeply rooted in the linguistic heritage of the region, are at risk of disappearing as dominant languages replace local dialects (Pieroni and Sõukand 2017). The loss of linguistic diversity limits the nuanced transmission of plant knowledge, as many terms carry specific cultural and ecological insights that are difficult to translate. For example, traditional uses of *Sideritis scardica* or *Thymus serpyllum* may be described differently in Bulgarian and Greek border sides, reflecting unique cultural contexts to which the two communities were attached during the past century (different Bulgarian and Greek centripetal centralization). Collected from the diverse landscapes of the region, some species such as *Chenopodium album*, *Cichorium intybus*, and *Rumex patientia* are valued not only for their nutritional content but also for their medicinal properties and cultural significance (Chute and Dakhane 2024; Łuczaj and Dolina 2015; Sulaiman et al. 2023). These plants are traditionally consumed as part of seasonal dishes and medicinal teas or preserved for later use.

The hybrid nature of plant knowledge in the Rhodope Mountains is another area of uncertainty. This region has been a crossroads of cultures for centuries, and Greek, Bulgarian, Ottoman, and other influences have intertwined (Kouli 2020; Valtchinova 2019a, b).

The ethnobotanical landscape of the Rhodope Mountains is deeply intertwined with the region's long-standing pastoral traditions. For centuries, transhumant and semi-nomadic pastoralism have not only shaped land use and vegetation patterns but have also fostered a rich repository of TEK concerning wild edible plants (Fernández-Giménez and Estaque 2012; Ivanova and Krastev 2023). Herders and shepherds, during their seasonal migrations and stays in remote pastures, relied on various wild plants for sustenance and medicinal purposes. Species such as *Urtica dioica*, *Rumex* spp., and *Thymus serpyllum* were commonly consumed or used in traditional remedies, reflecting a deep understanding of the local flora (Nedelcheva and Dogan 2019). This intimate relationship between pastoral practices and plant knowledge has contributed to the preservation of ethnobotanical traditions, especially in isolated communities where livestock rearing remains prevalent. However, contemporary challenges, including socioeconomic changes and depopulation, have led to the erosion of this knowledge base (Fernández-Giménez and Estaque 2012). Our study contributes to documenting and highlighting these traditional practices, representing one of the few in-depth efforts focused on the Rhodopes and surrounding regions, where such connections between wild edible plants and pastoral livelihoods remain underexplored. While we document current practices, it remains to be seen how knowledge about plants circulated historically through trade, migration, or shared agricultural practices. This uncertainty concerns the origins and development of specific uses, such as the semi-domestication of plants like *Prunus avium* and *Ribes nigrum*. It remains unclear whether these practices emerged independently within local communities or resulted from cultural exchange, especially after the formerly sealed state borders (1945–1990) became more permeable following the end of communism in Bulgaria three decades ago.

Despite these challenges, wild plants and mushrooms play a significant role in local communities' social and cultural lives. Traditional preparations, such as teas, syrups, and pies, serve not only as sustenance but also as markers of cultural identity. The communal preparation of herbal teas, particularly those using *Achillea millefolium* and *Mentha spicata*, plays a significant role in fostering intergenerational bonding and strengthening a sense of belonging to the land. In Bulgarian communities, these traditional practices are highly valued, with *Achillea millefolium* being regarded as a symbol of health and authenticity, contributing to the preservation of cultural heritage (Mincheva et al. 2019).

In Greek communities, the erosion of these practices due to urbanization and socio-economic shifts underscores the fragile nature of ethnobotanical traditions. This decline has broader implications, including the loss of communal rituals

and a diminished connection to the region's natural heritage. For example, studies have shown a decline in wild green foraging in areas like Corfu over the past 50 years, attributed to the increasing trend of urbanization and socio-economic changes (Alrhmoun et al. 2025). Moreover, rural depopulation in Greece has further contributed to the loss of ethnobotanical knowledge as younger generations migrate to urban areas, resulting in a disconnection from traditional plant use. The preservation of cultural landscapes, such as those in the Mani Peninsula, has also been highlighted as crucial for sustaining traditional practices. However, the erosion of these landscapes, driven by urbanization, threatens the continuity of these traditions (Oikonomopoulou et al. 2023).

Bulgarian communities maintain strong foraging traditions through oral transmission, communal events, and culinary practices, whereas Greek communities face a gradual erosion of these traditions. The preference for traditional preparations, such as herbal teas and syrups, reflects a collective memory and cultural identity deeply tied to the land. These preparations are not merely pragmatic but carry symbolic and ritual significance (Alrhmoun et al. 2025; Mincheva et al. 2019). In Bulgaria, ethnobotanical practices remain a core element of rural life, with local plants being harvested for medicinal and culinary uses as part of a broader strategy to maintain cultural heritage. Meanwhile, urbanization and socioeconomic changes in Greece are contributing to a shift away from these traditions, highlighting the need for measures to preserve the remaining ethnobotanical knowledge (Oikonomopoulou et al. 2023). For example, the use of *Thymus serpyllum* for herbal tea is valued for its medicinal benefits and as a nostalgic link to ancestral practices. Bulgarian communities continue to favor these methods over modern alternatives, demonstrating the resilience of cultural heritage.

Conservation strategies must address the intertwined ecological, cultural, and socio-economic dimensions to ensure the survival of this knowledge. Educational programs, community workshops, and sustainable tourism initiatives can revitalize interest in foraging and traditional preparations. Furthermore, efforts to document local plant and mushroom names and linguistic nuances are crucial for preserving the region's intangible cultural heritage.

Limitations of the Study

While this study provides valuable insights into plant and fungal foraging practices in the Rhodope Mountains, several limitations must be acknowledged. First, although the overall sample size was relatively modest, it reflected the diversity of local knowledge across the region. Thematic saturation was reached early in the fieldwork, suggesting that the main trends in wild plant and fungal use were effectively captured. Second, communication challenges arose during data collection, as many participants spoke local dialects or minority languages. In some cases, translation or interpretation was required, which may have affected the depth or precision of responses. Third, the study did not incorporate detailed demographic data such as participants' education levels, socio-economic status, or individual life histories, factors that can influence ethnobotanical knowledge. Similarly, although respondents represented multiple generations, the study did not explicitly analyze intergenerational knowledge transmission. Additionally, the wide geographical scope provided ecological and cultural diversity but may have limited the depth possible within specific localities. Lastly, the scarcity of prior scientific literature specifically focused on this transboundary region of the Rhodopes posed challenges for comparative contextualization.

Conclusion

This study provides a detailed documentation of ethnobotanical knowledge within the Rhodope Mountains, emphasizing distinctive patterns of wild plant and fungal use by communities on both sides of the Bulgaria-Greece border. Our data demonstrate that Bulgarian participants reported a notably higher species richness and frequency of plant citations compared to Greek participants, suggesting a stronger retention or active practice of traditional foraging knowledge in Bulgarian communities. This difference indicates potential variations or shifts in foraging practices between the two communities.

Sideritis scardica holds particular importance in the Bulgarian Rhodopes, where its frequent citation (by over 70% of participants) reflects its use in treating respiratory conditions tied to the region's cooler, mountainous climate. Meanwhile, *Origanum vulgare* is culturally significant across

both sides but shows variation in subspecies use, linked to microhabitat differences influencing local harvesting practices. The integration of wild, semi-domesticated, and cultivated species illustrates adaptive management shaped by ecological and socio-economic factors unique to these border communities. Despite sample limitations, these findings lay the groundwork for targeted studies on knowledge transmission and conservation strategies tailored to the Rhodope's biocultural landscape.

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Author Contributions

"M.A. conceptualisation, methodological frame, data analysis, visualisation, formal analysis, and writing the original draft. N.S. conceptualisation, methodological frame, review, and editing the manuscript. AN supervision, conceptualisation, methodology, field data collection, interviews and transcripts, botanical and fungal data curation, funding, review, and editing the manuscript. I.U. botanical and fungal data curation, review, and editing the manuscript. V.G. field data collection, logistics, review, and editing the manuscript. A.P. supervision, conceptualisation, research design, methodology, field data collection, funding, review, and editing the manuscript. All authors have read and agreed to the published version of the manuscript.

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Data Availability

No datasets were generated or analysed during the current study.

Declarations

Ethics Approval The study adhered to the International Society of Ethnobiology (ISE) Code of Ethics (https://www.ethnobiology.net/what-we-do/core-programs/ise-ethics-program/code-of-ethics/). Prior to conducting interviews, informed consent was obtained from all participants. Participants were fully briefed on the purpose of the research, the methods used, and their rights, including the voluntary nature of participation and the option to withdraw at any time without consequence. No personal or identifying information was collected, and data were anonymized to ensure confidentiality. The research team maintained respectful engagement with local communities and emphasized reciprocity through knowledge sharing and feedback sessions where possible. Formal ethics approval was not required under the regulations of the institutions involved; however, the study was conducted in accordance with widely accepted ethical standards for field research in ethnobotany.

Conflict of Interest The authors declare no competing interests.

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