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Review

Medicinal and Aromatic Plant Diversity of Greece: Biodiversity Knowledge, Ethnobotany and Sustainable Use—A Short Review

Alexandra D. Solomou [1,*], Aikaterini Molla [2] and Elpiniki Skoufogianni [3,†]

[1] Institute of Mediterranean Forest Ecosystems (IMFE), Hellenic Agricultural Organization-DIMITRA (ELGO-DIMITRA) Terma Alkmanos, Ilisia, 11528 Athens, Greece
[2] Hellenic Republic, Ministry of Rural Development and Food, Acharnon 2 Street, 10176 Athens, Greece
[3] Laboratory of Agronomy and Applied Crop Physiology, Department of Agriculture, Crop Production and Rural Environment, University of Thessaly, 38446 Volos, Greece
* Correspondence: asolomou@elgo.gr; Tel.: +30-2107787535 (ext. 170)
† Deceased author.

Abstract

Greece lies within the Mediterranean global biodiversity hotspot and harbors exceptional plant richness and endemism, including numerous medicinal and aromatic plants (MAPs). These taxa underpin long ethnobotanical traditions and contemporary bioeconomy niches (culinary herbs, essential oils, phototherapeutics). The aim of this review is to map (i) the biodiversity knowledge base for Greek MAPs, (ii) recent ethnobotanical evidence, and (iii) sustainability pathways (conservation, cultivation, value chains, and regulation) in a Mediterranean context. The information is presented and analyzed in a critical manner. A total of 148 research studies were systematically reviewed based on the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) guidelines. Key findings highlight that (i) Greece is a regional plant-diversity hotspot with many MAP endemics in Lamiaceae; (ii) contemporary ethnobotanical knowledge persists and adapts; and (iii) strong sustainability levers exist through Natura 2000 coverage, Good Agricultural and Collection Practice (GACP) and European Medicines Agency (EMA) frameworks, and Protected Designation of Origin (PDO)/United Nations Educational, Scientific and Cultural Organization (UNESCO) recognitions (e.g., Krokos Kozanis saffron, Chios mastic), although threats from climate and land-use change remain significant. In conclusion, Greek MAPs combine high biodiversity value, living ethnobotanical traditions, and tangible bioeconomic opportunities. Their sustainable prospects depend on integrating habitat protection, GACP and FairWild Standard (FairWild)-aligned wild collection and cultivation, domestication of priority endemics, and climate-resilience planning, all supported by traceable value chains and Access and Benefit-Sharing (ABS)/Nagoya Protocol compliance. The review concludes with practical recommendations and a prioritized list of flagship taxa for "conservation through use."

Keywords: Greece; Mediterranean; medicinal and aromatic plants (MAPs); ethnobotany; essential oils; Natura 2000; Nagoya Protocol; sustainability; climate change

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1. Introduction

The Mediterranean Basin is a classic global biodiversity hotspot, harboring around 25,000 native plant species, more than half of which are endemic to the region [1,2]. Contemporary national checklists and floristic portals (e.g., Vascular Plants of Greece and the Flora of Greece web portal) corroborate Greece's exceptional vascular plant richness currently documented as 5987 species and 2011 subspecies (native and naturalized) (representing 6867 taxa), including ~1.140 taxa of medicinal and aromatic plants (MAPs) (~20% of the total) providing a robust baseline for understanding the distribution and conservation status of medicinal and aromatic plants [3,4]. In this context, MAP-rich families, especially Lamiaceae (*Sideritis* sp., *Origanum* sp., *Thymbra* sp., *Salvia* sp., *Mentha* sp., etc.), are disproportionately represented in the Hellenic flora and deeply embedded in biocultural practices [3–7]. These taxa underpin culinary and medicinal traditions, supply essential-oil and herbal markets, and support place-based products (e.g., Chios mastic (Figure 1), Kozani saffron) that exemplify "conservation-through-use" pathways linking biodiversity stewardship to rural livelihoods and premium, traceable value chains [3–6].

Figure 1. Droplets of natural mastic resin on the trunk of *Pistacia lentiscus* L. var. *chia* Poir., alongside a typical cultivated tree found on Chios Island.

The significance of Greek biodiversity for MAPs extends beyond species counts. High spatial β diversity across islands, mountains, and coastal systems translates into rich phytochemical variation and locally adapted germplasm assets for quality, innovation, and climate resilience. Endemic and native Lamiaceae deliver multiple ecosystem services, spanning provisioning (herbal raw materials, essential oils), regulating (pollinator resources, landscape stability), and cultural values (ritual, cuisine, and identity) [5]. Because many MAPs occur in habitats covered by the Natura 2000 network, conservation planning can be directly coupled with sustainable use; Greece's Prioritized Action Framework (PAF 2021–2027) provides a vehicle to align site protection, monitoring, and community engagement with nature positive value chains [6]. In parallel, European and international standards (World Health Organization (WHO) and Food and Agriculture Organization of the United Nations (FAO) Good Agricultural and Collection Practices (GACP); European Medicines Agency (EMA) Committee on Herbal Medicinal Products (HMPC) herbal monographs), certification schemes (FairWild), and legal frameworks for access and benefit sharing (ABS/Nagoya) offer concrete mechanisms to operationalize quality, traceability, and equity from source to shelf.

At the same time, converging pressures from climate and land-use change, localized overharvesting, and globalized markets raise sustainability concerns typical of Mediterranean hotspots [8–10]. Scenario-based suitability modeling and climate-change dependence analyses for Greek MAPs, e.g., ex situ conservation planning for wild medicinal plants in Crete highlight increasing exposure to shifting temperature and precipitation regimes and land-use transitions that can fragment habitats and erode wild populations if unmanaged [11]. An integrated, evidence-based synthesis is therefore timely: one that documents what is known about Greek MAP biodiversity and use, identifies gaps that limit stewardship and innovation, and distills practical levers policy, standards, and community practice to safeguard resources while supporting resilient livelihoods [3–6].

Accordingly, this review maps the biodiversity, ethnobotany, and sustainability of Greek MAPs in their Mediterranean context and formulates actionable recommendations for research, conservation, and policy (e.g., Natura 2000/PAF, GACP, EMA monographs, Fair Wild, and ABS/Nagoya). We adopt a PRISMA to accommodate heterogeneous evidence bases transparently and to produce a narrative synthesis that connects ecological baselines to value chain and regulatory touchpoints [12–14].

2. Literature Review

2.1. Search Strategy and Selection Criteria

This study followed PRISMA guidance for transparent reporting of evidence identification, screening, and inclusion and used a scoping review logic to map heterogeneous evidence across biodiversity, ethnobotany, phytochemistry, soil management, and sustainability/policy dimensions relevant to medicinal and aromatic plants (MAPs) in Greece (PRISMA statement and PRISMA 2020 update [12–14]). The literature search was carried out on 30 December 2025, and this date was used as the cut-off point for record eligibility. We targeted publications from 2000 to 2025 to capture contemporary evidence relevant to current biodiversity baselines, value chains, and regulatory/quality frameworks.

Databases and coverage. Comprehensive searches were conducted in Scopus (primary bibliographic database) and extended to Google Scholar to capture complementary materials that may be under-represented in indexed databases (e.g., institutional reports, standards/guidelines, policy/regulatory documents, and authoritative online resources). Search strings were adapted to the syntax of each database while retaining the same conceptual structure. Records retrieved from both sources were exported to reference management Zotero version 7.0.30 (released 20 November 2025), and duplicate records were removed prior to screening.

Search terms. The search strategy combined geography terms with topical terms relevant to Greek MAPs and the review's thematic scope. The main keywords included combinations of "Greece" OR "Greek" AND ("medicinal and aromatic plants" OR "MAPs" OR "aromatic plants" OR "essential oil" OR "phytochemistry" OR "biodiversity" OR "ethnobotany" OR "ethnopharmacy" OR "conservation" OR "soil management" OR "sustainability"). Where needed, additional targeted searches were performed for flagship taxa and policy/standard terms (e.g., Natura 2000, GACP, EMA/HMPC, FairWild, ABS/Nagoya) to ensure coverage of the regulatory and sustainability dimensions.

Eligibility criteria. Records were included if they met all of the following criteria:

(i) Language: full text available in English or Greek;
(ii) Publication type: peer-reviewed journal articles and book chapters, plus authoritative institutional reports, official databases, and recognized guidelines/standards relevant to Greek MAPs (used primarily for policy/standards context rather than as equivalent evidence to empirical studies);
(iii) Topical scope: directly addressed at least one aspect of Greek MAPs within the review scope (biodiversity context, ethnobotany/uses, phytochemistry/bioactivity, soil management, sustainability/policy, flagship taxa);
(iv) Geographic relevance: focused on Greece, and/or explicitly included Greek MAP species/populations, Greek case studies, Greek supply/value chains, or Greek-relevant evidence. Evidence from the broader Mediterranean context was retained

only when it directly informed Greek MAPs (e.g., shared taxa with explicit Greek relevance, or Mediterranean sustainability frameworks applied to Greek systems);

(v) Time window: published between 2000 and 2025.

Records were excluded if they met any of the following criteria:

(i) Conference abstracts, posters, or other formats without sufficient methodological detail;
(ii) Theses/dissertations (if excluded by the study design) and other non-retrievable outputs;
(iii) Studies where the full text was not accessible;
(iv) General reviews or broad conceptual papers not explicitly linked to Greece or Greek MAP taxa/context;
(v) Records not relevant to the review's MAP-focused themes after title/abstract and full-text screening.

Screening process and final inclusion. The initial search yielded N = 283 records. After duplicate removal and initial screening, records were screened in two stages: (1) title/abstract screening against the eligibility criteria and (2) full-text assessment for inclusion. At full-text stage, we evaluated each record against the review's predefined thematic framework (see below). Excluded records and reasons for exclusion were documented. The full selection process is summarized in the revised PRISMA flow diagram (Figure 2). The final dataset included N = 148 records retained for synthesis.

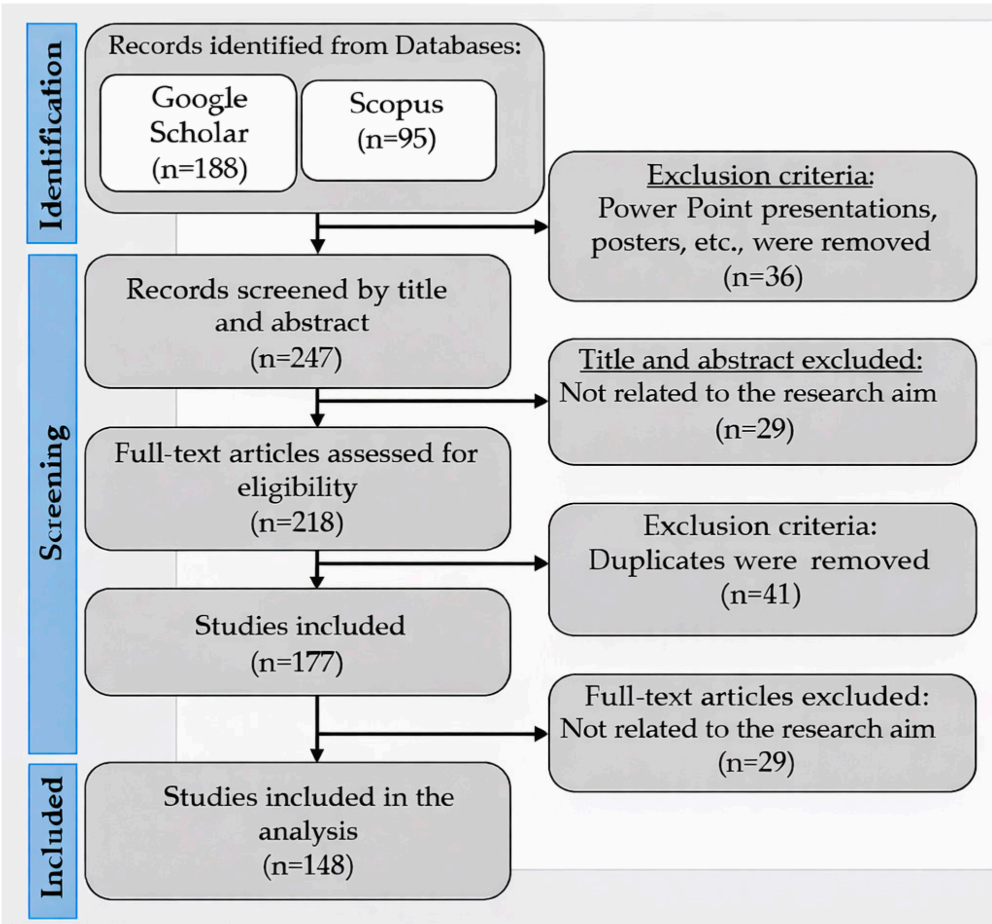

Figure 2. PRISMA flow diagram summarizing identification, screening, eligibility assessment, and inclusion of records for the scoping review (2000–2025).

2.2. Thematic Framework ("Key Aspects") and Data Extraction

To operationalize the "key aspects" used for final selection and synthesis, all eligible full-text records were coded against six predefined themes (focal points) that structure the Results section: (i) Biodiversity context of Greek MAPs in the Mediterranean; (ii) Ethnobotany and uses: living traditions and modern evidence; (iii) Phytochemistry and biological activity; (iv) Soil management; (v) Sustainable prospects: conservation-through-use, standards, and policy; and (vi) Flagship taxa synthesis and practical integration. For final inclusion in the synthesis, records were required to contribute substantive evidence to at least two of these six themes (e.g., biodiversity + ethnobotany; phytochemistry + bioactivity; sustainability policy + flagship taxa).

For each included record, we extracted bibliographic information (year, publication type), focal taxa (where applicable), geographic context (Greek region/island/mainland; or Greek-relevant Mediterranean context), and the main findings relevant to the coded theme(s). Given the heterogeneity of evidence types (ecological baselines, ethnobotanical surveys, chemical profiling, agronomy/soil studies, and policy/standard documents), we conducted a structured narrative synthesis rather than a quantitative meta-analysis. The distribution of included records by publication type and time period is presented in Figure 3.

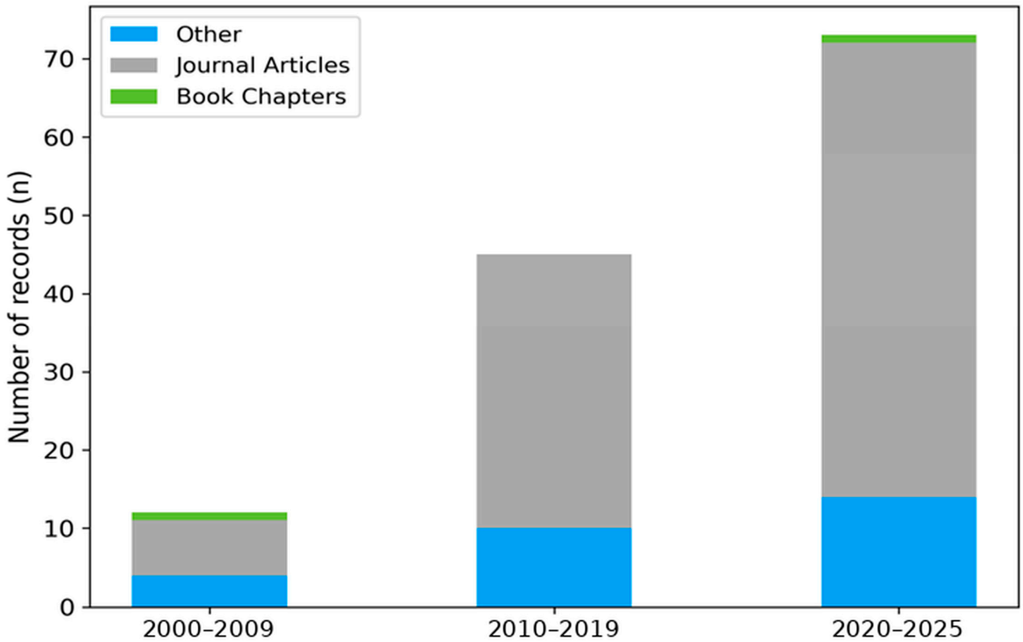

Figure 3. Distribution of bibliographic records used in this study across three time periods (2000–2009, 2010–2019, and 2020–2025), classified into journal articles, book chapters, and other sources (e.g., institutional reports, regulations/guidelines, and authoritative online resources).

3. Biodiversity Context of Greek MAPs in the Mediterranean

Quantitative Synthesis of Taxonomic and Functional Diversity (Floristic Context and Use-Related Traits)

Greece hosts a highly diverse vascular flora. The updated national checklist reports 6620 native taxa (species and subspecies) belonging to 1073 genera and 185 families, comprising 5758 species and 1970 subspecies [3]. Greek floristic distinctiveness is further supported by a high level of endemism, with 1459 endemic taxa (~22%), including 1274 endemic species and 450 endemic subspecies [3].

To provide a standardized statistical baseline for interpreting medicinal-plant diversity patterns, we summarize functional traits (life forms) and broad habitat affiliations using the national checklist framework [3,4]. Life-form assignments indicate a predominance of perennating taxa (ca. 75%), while therophytes contribute approximately 25%, consistent with the Mediterranean climate and disturbance regimes [4]. The most frequent life-form categories are hemicryptophytes and therophytes (Figure 4) [4]. Regarding ecological setting, habitat-category assignments show that taxa are most frequently associated with agricultural/ruderal habitats (R, 18.1%) and grasslands (G, 17.7%), followed by phrygana (P, 15.4%) and woodland (W, 13.7%) (Figure 5) [3]. In contrast, endemic taxa exhibit a marked shift toward cliffs/rocks/walls (C, 22.9%), high-mountain habitats (H, 19.9%), and phrygana (P, 19.3%), underscoring the importance of topographically complex and stress-prone habitats for local floristic uniqueness (Figure 5) [3].

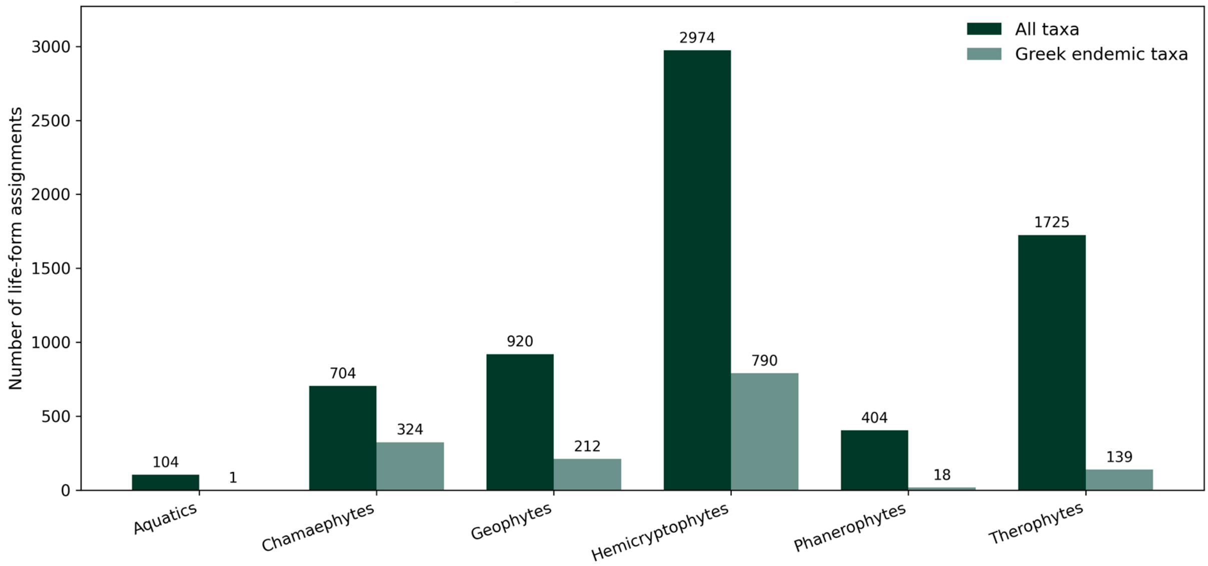

Figure 4. Life-form assignments in the vascular flora of Greece (all taxa vs. Greek endemic taxa).

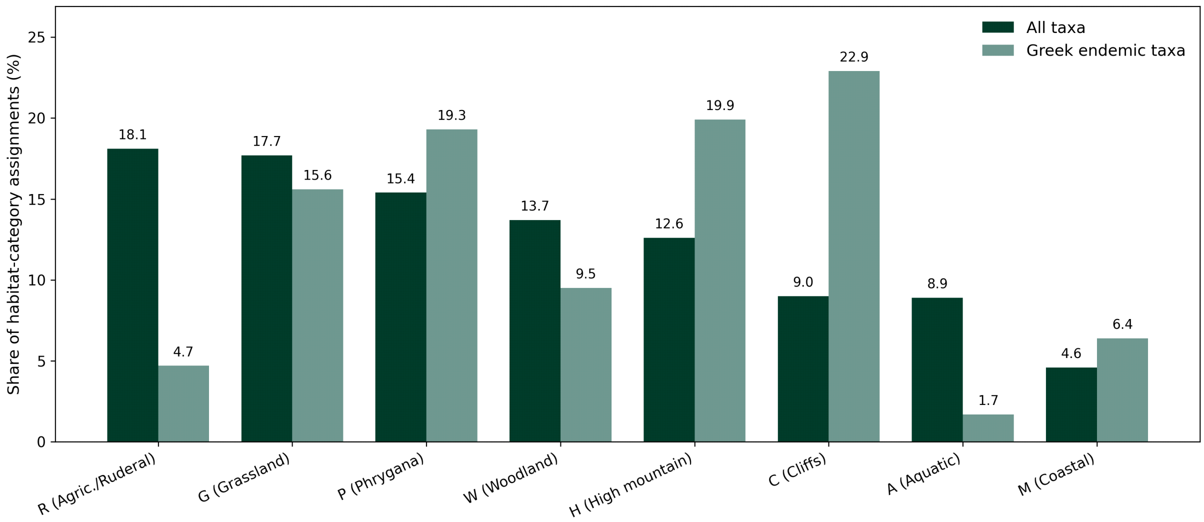

Figure 5. Habitat-category assignments in the vascular flora of Greece (all taxa vs. Greek endemic taxa).

At the family level, this review additionally incorporates a statistical synopsis table (Table 1) to facilitate comparison across major medicinal-plant families (species richness, percentage contribution, representative taxa, dominant phytochemical classes, and use/conservation notes).

Table 1. Family-level statistical synopsis (species richness and MAP-relevant synopsis) for selected major plant families in Greece [3,4,15–24].

Family	Species in Greece (n)	% of Greek Species	Representative Medicinal/Aromatic Taxa in Greece (Examples)	Dominant Phytochemical Classes/Marker Compounds (Examples)	Indicative Efficacy/Traditional Uses (Examples; Evidence Base)	Use and Conservation Notes (Greece)
Lamiaceae	260	4.52%	*Origanum vulgare* subsp. *hirtum*, *Thymus* sp., *Salvia* sp., *Sideritis* sp.	EO phenolic monoterpenes (carvacrol, thymol); polyphenols (e.g., rosmarinic-acid derivatives); phenylethanoid glycosides in *Sideritis* sp.	Oregano EO: bioactivity beyond antimicrobial, including broad bioactivity profile linked to key EO constituents.	High MAP relevance and high endemicity: 414 Lamiaceae taxa recorded in Greece; includes 111 Greek endemic taxa (88 endemic species). Endemic-rich genera (e.g., Sideritis) require harvest management; at least some emblematic taxa have IUCN assessments (e.g., *Sideritis scardica*).
Asteraceae	749	13.02%	*Matricaria recutita*, *Silybum marianum*, *Achillea* sp.	Flavonoids; sesquiterpene lactones; for *Silybum*: flavonolignans (silymarin)	Chamomile flower: traditional use for minor GI complaints (bloating/spasms), common cold symptom relief, oral/throat inflammation, minor skin inflammation, etc. Milk thistle fruit: supportive treatment (e.g., alcoholic liver disease) and traditional use for digestive disorders with fullness/bloating/flatulence.	Large family; many taxa are widespread and commonly collected/cultivated (e.g., chamomile), but also includes local endemics—recommend emphasizing traceability/quality standards for traded material.
Fabaceae	438	7.61%	*Glycyrrhiza* sp., *Trigonella foenum-graecum*	Triterpenoid saponins (e.g., glycyrrhizin); isoflavones; polysaccharides	Liquorice root: traditional use for digestive symptoms (burning sensation/dyspepsia) and as expectorant in cough associated with cold.	Mainly cultivated/managed supply chains for key medicinal taxa; ensure attention to correct species ID and quality specs (Ph. Eur./monographs) for market products.

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Table 1. *Cont.*

Family	Species in Greece (n)	% of Greek Species	Representative Medicinal/Aromatic Taxa in Greece (Examples)	Dominant Phytochemical Classes/Marker Compounds (Examples)	Indicative Efficacy/Traditional Uses (Examples; Evidence Base)	Use and Conservation Notes (Greece)
Brassicaceae	278	4.83%	*Sisymbrium officinale*, *Capsella* sp., *Sinapis* sp.	Glucosinolates and derived isothiocyanates (family-typical); mucilage in some taxa	Example monographic use exists for Sisymbrium officinale in EU herbal assessment/monograph frameworks (traditional "throat/voice" uses in European herbal medicine).	Several taxa occur as ruderal/widespread plants; some medicinal uses rely on traditional practice—recommend clear differentiation between food uses and medicinal indications.
Apiaceae	230	4.00%	*Foeniculum vulgare*, *Pimpinella anisum*, *Coriandrum sativum*	Essential oils (e.g., trans-anethole in fennel/anise types); coumarins (family-typical)	Sweet fennel fruit: traditional herbal medicinal product for mild spasmodic GI complaints incl. bloating/flatulence.	Includes both widely used cultivated MAPs and toxic look-alikes in the family—recommend explicit safety note on correct botanical identification for wild collection.
Rosaceae	152	2.64%	*Rosa* sp., *Crataegus* sp., *Rubus* sp.	Polyphenols (flavonoids, procyanidins), tannins; vitamin C-rich fruits (some taxa)	Widely used in traditional medicine as antioxidant/astringent and for cardiometabolic-support preparations (hawthorn uses documented in European herbal medicine practice).	Many taxa harvested from wild shrubs/trees; generally lower endemism pressure compared with Lamiaceae mountain endemics, but local over-collection may occur for popular fruits/flowers—recommend local sustainability note where relevant.

As an example of the local distinctiveness that can be masked without quantitative synthesis, Lamiaceae comprises 414 taxa in Greece, including 111 Greek endemic taxa [15–17]. Beyond its high medicinal relevance in the broader Mediterranean ethnobotanical record (e.g., Lamiaceae among the most reported families) [25], the Greek component of the family includes range-restricted taxa with documented conservation and sustainable-use relevance (e.g., local endemics under protection measures and/or cultivation initiatives) [26–28]. Chemically, aromatic Lamiaceae are frequently characterized by essential-oil mono- and sesquiterpenes and phenolic monoterpenoids (e.g., carvacrol, thymol and related compounds), which have well-documented antimicrobial/biological activities in the literature [25,29]. Similar patterns of strong antibacterial activity linked to high carvacrol content are also reported for Greek mountain-tea taxa (*Sideritis* sp.) in the essential-oil literature [27].

Finally, to summarize use-related traits, we include a comparative chart of medicinal plant parts most frequently utilized in an ethnobotanical dataset from the North Aegean (Figure 6), where leaves (22.8%), roots (12.78%) and flowers (11.41%) dominate among reported plant parts [30]. These patterns provide a standardized interpretive lens for the diversity of remedies (plant parts and preparations) described in Greece and help highlight where endemic/range-restricted taxa intersect with harvesting pressure and sustainability considerations [17,27,28].

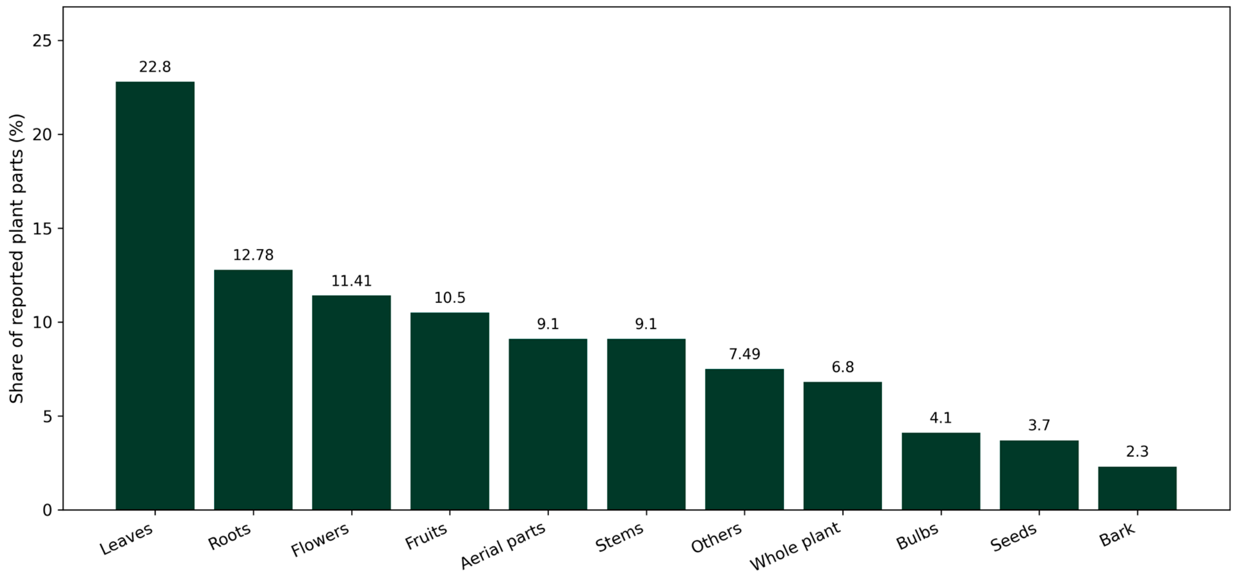

Figure 6. Medicinal plant parts used in an ethnobotanical dataset from the North Aegean islands (percent share of reported plant parts).

4. Ethnobotany and Uses: Living Traditions and Modern Evidence

Ethnobotanical knowledge around MAPs remains vibrant in Greece, though regionally differentiated. A 2019 study in Central Macedonia documented traditional medicinal uses across communities, showing continuity and adaptation in plant knowledge and uses [31]. The Thessaloniki herbal market analysis (2004) showed that commercial herbal trade remains grounded in regional ethnobotanical traditions indicative of how knowledge flows into urban markets [32]. Island communities maintain distinctive repertoires shaped by insularity and endemism, complementing mainland patterns. Contemporary ethnobiology work in Greece and the broader Mediterranean has also examined local knowledge of sustainable harvesting and availability of wild medicinal plants, emphasizing the value of community practice and place-based management [33]. Culturally emblematic species illustrate the knowledge-to-innovation pathway: Greek mountain teas (*Sideritis scardica*

Griseb., *Sideritis raeseri* Boiss. & Heldr., *Sideritis syriaca* L.); oregano (*Origanum vulgare* L. subsp. *hirtum* (Link) A.Terracc.) and thyme relatives (*Thymbra capitata* (L.) Cav.) underpin culinary and antimicrobial traditions; Greek sage (*Salvia fruticosa* Mill.) is used for aromatic infusions; Chios mastic (*Pistacia lentiscus* L. var. *chia* Poir.) and Kozani saffron (*Crocus sativus* L.) anchor place-based economies [34].

5. Phytochemistry and Biological Activity of Flagship Greek MAPs

In the flagship Greek medicinal and aromatic plants (MAPs), bioactivity is closely linked to well-defined chemotypes comprising polyphenols and terpenoids. *Sideritis* sp. ("mountain tea") infusions are particularly rich in hydroxycinnamic acids (e.g., caffeic acid), phenylpropanoid/phenylethanoid glycosides (notably verbascoside/acteoside), and flavone glycosides derived mainly from isoscutellarein, methylisoscutellarein, and hypolaetin, which often occur as highly abundant constituents in the aqueous preparation [35]. In parallel, the essential oils of cultivated Greek Sideritis species are dominated by oxygenated monoterpenes and related volatiles, including linalool, α-terpineol, myrtenol, trans-pinocarveol, and verbenone, supporting reported antimicrobial and antioxidant effects [36].

For Greek oregano (*O. vulgare* subsp. *hirtum*), the polar phenolic fraction frequently contains rosmarinic acid and salvianolic acid B, alongside other phenolics, while the volatile fraction is characterized by phenolic monoterpenes such as carvacrol (and, depending on chemotype, thymol) [37]. Across oregano accessions, targeted profiling commonly detects multiple individual phenolic acids and flavonoids (e.g., caffeic-/rosmarinic-acid–related compounds and flavonoid derivatives), providing a mechanistic basis for strong antioxidant capacity [38]. In agronomic/plant-protection contexts, oregano essential oil and its major constituents thymol and carvacrol have been further highlighted as biologically active agents with antimicrobial relevance [39].

In *T. capitata*, there is common coexistence of carvacrol and monoterpene hydrocarbons such as p-cymene, γ-terpinene, and oxygenated monoterpenes (borneol); this latter profile has been found to be related to strong biological activity, including one kind of herbicidal effect in experimental systems [40].

Characteristic constituents of the *S. fruticosa* extracts included several metabolites that were quantified or repeatedly tentatively annotated: phenolic compounds rosmarinic acid (RA), salvianolic acid B (Sal-B), and caffeic acid and the flavonoid scutellarin; abietane-type diterpenes such as carnosic acid and carnosol; and possibly triterpenoids, tentatively annotated as ursolic acid. Collectively, these constituents may contribute to the observed antioxidant capacity and enzyme-inhibitory activity [41].For Chios mastic gum (*P. lentiscus* var. *chia*), chemical complexity derives from (i) a polymeric fraction (reported for the resin as cis-1,4-poly-β-myrcene), (ii) an essential-oil/volatile fraction, and (iii) a non-volatile terpenoid fraction enriched in triterpenes and triterpenic acids [42]. Importantly, the major characteristic triterpenic acids include 24Z-masticadienonic acid (MNA) and 24Z-isomasticadienonic acid (IMNA), which have been experimentally evaluated—along with semi-synthetic analogs—for anti-inflammatory activity [43].

Finally, saffron (*C. sativus*) is defined by apocarotenoid and flavonoid markers: its major stigma metabolites include crocetin esters (crocins), picrocrocin, and safranal, while other floral tissues contain additional phenolics such as kaempferol-related compounds; these constituents underpin antioxidant and broader bioactivity profiles reported for saffron preparations [44].

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6. Soil Management for Greek MAPs

6.1. Edaphic Diversity in Greek MAPs Habitats

Greek medicinal and aromatic plants (MAPs) are found across a wide range of Mediterranean landscapes characterized by pronounced edaphic heterogeneity. Typical Map habitats on mountains, limestone hills and island systems are dominated by shallow, stony, often calcareous soils with low organic matter content and a distinctly seasonal water regime. These soils are frequently skeletal, with limited water-holding capacity and high susceptibility to erosion, especially under intense rainfall events, overgrazing or inappropriate tillage [17].

Such edaphic conditions act as strong environmental filters that shape MAP assemblages and endemism, complementing the biogeographic patterns already highlighted for Greek Lamiaceae and other MAP-rich families [45,46]. In practice, the same geomorphological and climatic gradients that support the high diversity of MAPs also generate fragile soils that can be rapidly degraded if mismanaged [47].

6.2. Soil–Plant–Chemotype Interactions

For several flagship Greek MAPs, soil properties are important not only for establishment and yield but also for secondary metabolite profiles. Species such as *Sideritis scardica* Griseb., *S. raeseri*, *O. vulgare* subsp. *hirtum*, *T. capitata* and *S. fruticosa* typically occur on well-drained, moderately to highly calcareous soils where combined nutrient limitation and seasonal water stress are associated with relatively high essential oil content and characteristic chemotypes [48].

Key edaphic factors include soil reaction (pH and $CaCO_3$), texture and structure, soil organic matter content and biological activity. Many MAP habitats are alkaline and rich in calcium carbonate. High pH affects micronutrient availability and root physiology and may directly modulate biosynthetic pathways for terpenoids and phenolics, with environment-driven shifts in essential oil profiles documented for oregano and other MAPs [49–51]. Light to medium soil textures (sandy loam to loam) with good structure promote aeration, root penetration and rapid drainage—conditions preferred by many drought-tolerant MAPs—whereas heavy, compacted clays increase waterlogging and root diseases, often disfavoring typical Greek MAP assemblages. Moderate increases in soil organic matter can improve water retention and support soil biota, but overlay fertile conditions or high nitrogen inputs may shift plant allocation towards vegetative growth and reduce essential oil concentration, as known for Greek oregano and other aromatic crops under different fertilization and irrigation schemes [51,52]. Experimental studies on soil–chemotype relationships are still limited and often confounded by climatic and genetic factors. However, studies on oregano, basil and rosemary indicate that soil type and fertility can significantly affect essential oil composition and the relative abundance of key constituents, reinforcing the view that edaphic conditions must be considered alongside provenance, genotype and management when interpreting spatial variation in essential oil yield and composition and when designing cultivation schemes for quality-sensitive taxa [49,53,54].

6.3. Fertilization Strategies in MAPs (Mineral vs. Organic)

Fertilization is a key lever for aligning productivity, essential oil quality and environmental performance in medicinal and aromatic plants. In general, fertilization strategies must balance three partly competing goals: biomass production, essential oil yield and composition, and environmental sustainability [55,56].

Experimental work in Greek oregano (*O. vulgare* subsp. *hirtum*) has shown that moderate nitrogen fertilization (40–80 kg N ha^{-1}) increases dry biomass and essential oil yield, with no effects on oil concentration and composition beyond a certain threshold [51,52]. Higher mineral nitrogen (N) inputs tend to yield diminishing returns and may reduce essential oil content per unit dry weight, because additional nitrogen promotes vegetative growth and dilutes secondary metabolites on a dry-matter basis [52].

Similar NPK optimization studies for *O. dubium* and *S. cypria* under controlled or hydroponic conditions indicate that intermediate levels of N, P, and K maximize growth, nutrient and water use efficiency and in some cases phenolic and antioxidant traits. In contrast, excessive nutrient supply does not further improve and may even depress secondary metabolite levels [57,58]. In other MAPs, such as *Ocimum gratissimum* and *Ocimum basilicum*, higher mineral fertilizer doses raise biomass and essential oil yield to a point, but quality responses are non-linear and species-specific: moderate N and K rates often increase oil yield without major changes in composition, whereas very high rates can reduce the relative content of key monoterpenes or phenylpropanoids and shift the chemotype [59,60]

Beyond nitrogen, phosphorus and potassium also play important roles in MAP performance. In basil, thyme, and coriander, balanced NPK fertilization improved plant height, branch number, leaf area, and essential oil yield compared with unfertilized controls [61–64]. However, the response plateaued at intermediate rates, and excessive K sometimes reduced oil content [62–64].

Mineral fertilization interacts strongly with water availability and plant density. In Greek oregano and other Lamiaceae, optimal N doses for maximum oil yield are typically lower under rainfed or deficit irrigation conditions, because water stress alone stimulates secondary-metabolite production, whereas under full irrigation somewhat higher N can be used without compromising oil quality. Similarly, in sage and mint, the positive effect of N on biomass is strongest at intermediate plant densities. Very dense canopies may suffer from self-shading and disease, while very sparse plantings underutilize applied nutrients [65].

In summary, mineral fertilization in MAPs should be viewed as a fine-tuning rather than a maximization strategy. Across species, moderate and well-balanced NPK inputs are sufficient to secure substantial gains in biomass and essential oil yield, whereas excessive fertilization tends to dilute secondary metabolites and increase environmental costs.

Organic fertilizers can, in many cases, be considered better than mineral fertilizers, not necessarily because they always result in higher yields, but because they improve the agro-ecosystem as a whole. They add organic matter and gradually enhance soil structure, stability, and water-holding capacity, while simultaneously stimulating microbial activity and the biodiversity of the soil biota [66,67]. Nutrient release occurs more gradually with these fertilizers, reducing the leaching, the salinization, and water contamination compared with the application of chemical fertilizers [68].

In MAPs, the supply of nutrient helps to achieve balanced growth, while at the same time limiting the vegetative growth, thus maintaining or enhancing the content and quality of essential oils [69–71]. In addition, the use of compost, manure, vermicompost, and other organic materials is associated with a lower energy footprint, the valorization of residues/wastes and a better overall sustainability profile, which is important for organic certified product markets. Thus, even if maximum yields are slightly lower, the quality of the system (soil, environment, product) is often higher compared with intensive mineral fertilization regimes [69,72].

Research on chamomile (*Matricaria chamomilla* L.) and other MAPs showed that the use of organic fertilization, such as compost, vermicompost, and other organic amendments, can help flower yield and essential oil production while improving soil health and, in some cases, altering the ratios of key oil compounds [73–75]. A field trial compared NPK fertilizer with compost and the results revealed that compost enhanced the flower yield and content of essential oil and the proportion of oil components [54].

One study combined inorganic and organic fertilization in rosemary (Rosmarinus officinalis L.) cultivation. This combined approach increased soil nutrient availability and biomass, while simultaneously modifying foliar terpenoid profiles, indicating that fertilization regimes can shift carbon allocation between structural and secondary metabolites [76–78].

A study with spearmint (*Mentha spicata* L.) showed that the use of vermicompost (10–15 t ha^{-1}) enhanced the growth, the antioxidant activity of the enzyme and the concentration of essential oil in comparison with chemical fertilizer. The data of this study support the use of environmentally friendly organic fertilizers in MAP production [65]. Vermicompost, which is made from plant residues, has been noted to increase *Dracocephalum kotschyi* Boiss. biomass and essential oil content. This means that vermicompost can be used as a sustainable nutrient source for MAPs [79].

The use of combined organic and mineral fertilization schemes show to be very promised [80]. Some studies show that organic fertilizers in MAP cultivation improve essential oil quality and enhance soil health. However, biomass growth may lag slightly compared to mineral fertilizer systems [73,81,82].

The literature on organic fertilization strategies in MAPs indicates that organic additions generally enhance soil organic matter content, biological activity, and nutrient regulation capacity. These additions often maintain or improve the quality of essential oils, while chemical fertilizers can reduce product quality and increase environmental risks [83,84].

Mediterranean case studies highlight the multifunctional role of organic and biofertilizers. Recent work on Cretan dittany (*O. dictamnus*) shows how organic fertilization can enhance both crop performance and biodiversity [85]. Organic and biofertilizers are increasingly used in Salvia officinalis cultivation under Mediterranean conditions. A bio-nitrogen fertilization, with combined appropriate irrigation and plant density, significantly improved plant height, leaf area index, chlorophyll index and dry leaf biomass compared with the unfertilized control, confirming the suitability of sage for organic cultivation [86]. Studies on other MAPs confirm that combining vermicompost with mineral NPK enhances rosemary biomass and oil yield, while that combination improves the soil fertility [87]. Moreover, animal manures, such as poultry manure, can increase the plant's biomass and essential oil yield in hyssop (Hyssopus officinalis) cultivation. That demonstrates that manure can be used to enhance productivity and phytochemical characteristics [88].

Taken together, these studies support the development of fertilization schemes for MAP cultivation in which organic fertilizers and biofertilizers play a significant role, either alone or in combination with chemical inputs.. Organic amendments, such as manure, compost, vermicompost and biofertilizers can improve the soil properties, improve biomass of the plants and enhance essential oil quality, favoring biodiversity at the same time [83,89].

7. Sustainable Prospects: Conservation-Through-Use, Standards and Policy

Protected areas and planning. The Natura 2000 network and Greece's PAF 2021–2027 provide a spatial and financial framework for conserving MAP habitats and guiding sustainable use; LIFE-IP 4 Natura and partners (e.g., WWF) support implementation and public engagement. Climate projections and land-use trajectories introduce uncertainty in both habitat conservation and cultivation planning; scenario-based suitability modeling for key Greek MAPs (e.g., wild medicinal plants in Crete) supports anticipatory, adaptive management within Natura 2000 landscapes [6,15]. Good practices and certification. The

WHO (2003) and FAO (2010) published GACP guidelines for medicinal plants; in 2025 the EMA/HMPC released Revision 1 of the EU GACP Guideline, aligning quality with sustainability in starting materials of herbal origin [49–51]. For wild collection, FairWild certification operationalizes ecological, social, and economic standards including traceability and fair benefit-sharing relevant for Greek MAP value chains (e.g., wild Sideritis, Origanum, resins) [52,53]. ABS/Nagoya and place-based quality schemes. The EU ABS framework and the Nagoya Protocol frame access and benefit-sharing; Greece's National Biodiversity Strategy and Action Plan (2014–2029) integrates CBD commitments. Geographical indications (PDO/PGI) add market-based conservation incentives (e.g., Krokos Kozanis PDO) [54–56]. Priority actions (Greece). (1) Prioritize endemics with high cultural/market value (e.g., *Sideritis* sp., *O. dictamnus*, *T. capitata*) for conservation-through-cultivation (ex situ seed/field banks; genetic characterization; chemotype stabilization); (2) operationalize GACP and, for wild resources, FairWild (harvest quotas, rotation, minimum cutting heights, collector training, community monitoring); (3) expand traceability (lot-based tracking, EO chemotypes linked to provenance, ABS documentation); (4) climate resilience: use suitability modeling for siting plantations and sourcing germplasm; (5) transdisciplinary ethnobotany to co-design sustainable harvest calendars and support knowledge holders; (6) promote PDO/PGI/UNESCO-style recognitions where appropriate; (7) build open national databases linking occurrence, chemistry, and use with Natura 2000 layers (leveraging Euro + Med and national portals).

8. Flagship Taxa and Practical Synthesis

Building on the preceding synthesis, this section highlights a set of flagship Greek MAP taxa that sit at the intersection of biodiversity value, ethnobotanical importance, phytochemical potential, and feasibility for sustainable use. Selection prioritized species that are native or endemic, culturally salient and/or commercially relevant, supported by recent phytochemical/biological evidence, and coupled with practical sustainability levers (e.g., Natura 2000 coverage, GACP/FairWild, EMA monographs, PDO/UNESCO). The objective is to translate evidence into action by pointing to taxa where conservation-through-use can be operationalized via cultivation or well-managed wild collection, provenance/chemotype standardization, traceable value chains, and ABS/Nagoya compliance.

We next synthesize the distribution of evidence across taxa and domains in an evidence heatmap (Figure 7).

There is non-proportional coverage of taxa and domains in the heatmap (Figure 7). Phytochemistry and bioactivity are relatively well documented for *Sideritis* sp. and *O. vulgare* ssp. *hirtum* and *T. capitata*, but the biodiversity/conservation and policy manuals are relatively scant for some species. In contrast, *P. lentiscus* and *C. sativus* are evidence-wise profiling (value chain/regulatory), a clustering of results for traditional protected products. These trends signal clear next steps: strengthening ecological baselines will remain a priority, integrating ethnobotanical knowledge directly into market systems is becoming increasingly important, and promoting a standardized framework for quality/traceability needs to inevitably expand into underrepresented sectors.

Table 2 summarizes, for each taxon, its distribution/status in Greece, key constituents and notes, evidenced uses, and concrete sustainability instruments to guide research, management, and market deployment. The list is illustrative (not exhaustive) and can be expanded as new evidence accrues. We then comprehensively discuss the findings by thematic axis, their implications for policy and practice, and immediate priorities.

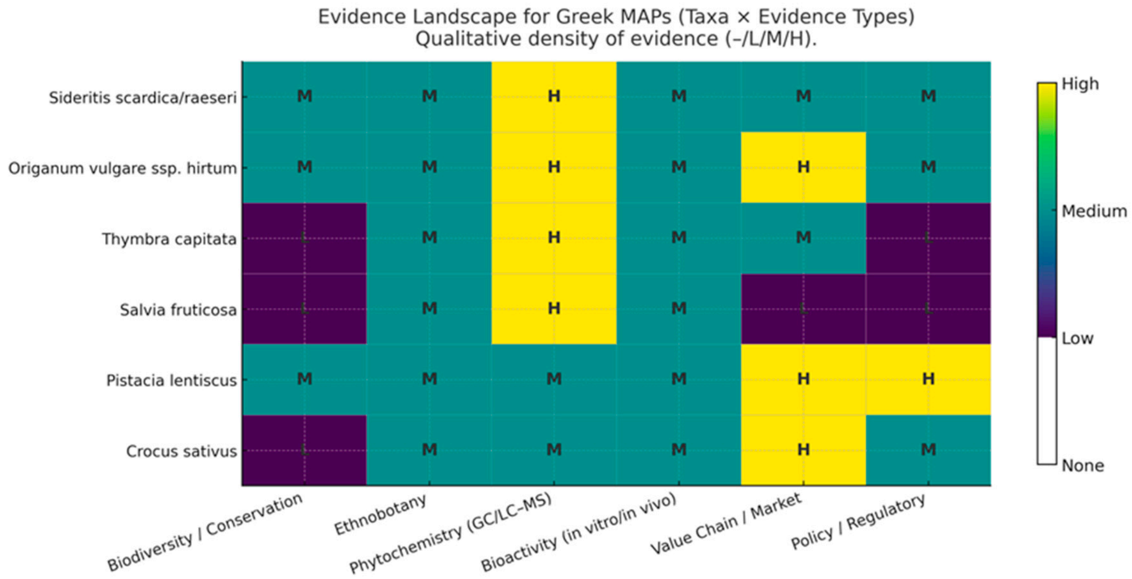

Figure 7. Evidence landscape for selected Greek medicinal and aromatic plants (MAPs). Cells summarize the density of evidence for each taxon across six domains (biodiversity/conservation, ethnobotany, phytochemistry, bioactivity, value chain/market, policy/regulatory) using a four-level scale (–/low/medium/high). The heatmap highlights evidence clusters and gaps, guiding priorities for research, stewardship and standardization.

Table 2. Flagship taxa and practical synthesis.

Taxon (Selected)	Distribution and Status (Greece)	Key Constituents/Notes	Evidenced Uses (Recent)	Sustainability Levers
S. scardica/S. raeseri/ S. syriaca	Balkan/Greek mountains; valued native/endemic complex	Polyphenols; terpenoids	Cognitive/anti-amyloid signals; traditional infusions	EMA Sideritis herba monograph; GACP; cultivation and ex situ; Fair Wild for wild stands [90–92].
O. vulgare subsp. *hirtum* (Greek oregano)	Native; widely used	EO rich in carvacrol/thymol	Antimicrobial/antioxidant; bioherbicidal	GACP cultivation; chemotype QA; ABS; Natura sourcing [93–96]
T. capitata	Native (Aegean coasts/Islands)	Carvacrol-rich EO	Strong antimicrobial and bioherbicidal activity	Managed wild collection; domestication where habitat-sensitive [97,98].
S. fruticosa (Greek sage)	Eastern Mediterranean; Greek populations variable	1,8-cineole major; chemovariation	Culinary/medicinal aromatic	Provenance selection; Ph. Eur. compliance; sustainable harvest [99,100].
P. lentiscus var. *chia* (Chios mastic)	Chios endemic agro-ecosystem	Resin (mastic)	GI/skin indications (EMA); cultural heritage	UNESCO ICH; EMA monograph; PDO/branding; landscape stewardship [93,101]
C. sativus (Krokos Kozanis)	Kozani (Macedonia)	Safranal, crocins	Culinary/medicinal; high-value spice	PDO; compositional QA; climate suitability mapping [94].

9. Discussion

Greece lies within the Mediterranean Basin, a globally recognized biodiversity hotspot, where exceptional vascular-plant richness and endemism are associated with strong environmental heterogeneity and long-term biogeographic complexity [102,103]. Within this broader hotspot, Greece (including Crete and the Aegean archipelagos) is repeatedly identified among the key centers of plant diversity and narrow endemism in the Mediterranean context [103,104]. Accordingly, Greek medicinal and aromatic plants (MAPs) discussed here include both (a) narrow-range endemics and island/mountain "micro-endemics" whose conservation logic is tightly coupled to place, and (b) more widely distributed Mediterranean taxa for which Greek provenance can remain distinctive through ecology-linked chemotypes, long-standing cultural embedding, and origin-based value chains [103,105].

Endemic and narrow-range distinctiveness (global comparison)**.** Cretan dittany (*Origanum dictamnus*) exemplifies a Greek endemic with strict geographic confinement (native to Crete) [106]. This makes its "conservation-through-use" framing fundamentally different from the global "oregano" market concept, which spans multiple *Origanum* taxa and multiple production regions. In the same vein, Greece hosts *Sideritis* taxa with highly localized distributions (e.g., *Sideritis euboea* restricted to Euboea), underscoring that "Greek mountain tea" is not a single interchangeable commodity but a biogeographically structured complex where locality can matter for both stewardship and product identity [107]. Such cases allow a clearer articulation of Greek distinctiveness precisely because the relevant comparison is international: similar-looking herbal products exist elsewhere, but the Greek endemics are not substitutable without changing the taxonomic identity and, in many cases, the cultural and ecological context of use.

Widespread congeners and the meaning of "Greek origin" (quality and authenticity in global trade). Some flagship taxa are not strictly endemic yet remain locally distinctive because Greek populations occupy characteristic ecological settings (often calcareous, water-limited island/mountain systems) that are frequently associated with stable, provenance-linked phytochemical profiles relevant to quality and market differentiation [103,108]. For example, "Greek oregano" (*Origanum vulgare* subsp. *hirtum*) is native across a broader SE European–Anatolian range [108], yet comparative work explicitly benchmarks Greek oregano against "common oregano" (subsp. *vulgare*) cultivated under Central European temperate conditions, demonstrating how geographic provenance can be integral to "quality framing" (e.g., essential-oil yield and chemotype differences) [105]. At the same time, oregano is repeatedly highlighted as a high-vulnerability botanical in international supply chains; robust, multimodal authentication approaches (e.g., spectroscopy and HRMS as well as DNA- and NMR-based methods) are increasingly necessary to protect origin claims and reduce adulteration—an issue that directly elevates the value of well-defined Greek provenance [109–111].

Place-based products in global comparison: institutionalized distinctiveness. Two emblematic Greek products illustrate how local distinctiveness is reinforced through formal protection and standardization. Chios mastic is a geographically delimited resin protected as an EU PDO (original EU registration: 24 January 1997) and its cultivation know-how is inscribed by UNESCO [93], collectively differentiating it from more generic resin supply chains by tying quality and stewardship to a defined cultural landscape [112–114]. Likewise, "Krokos Kozanis" saffron is anchored to a specific Greek production area under PDO protection (original EU registration: 20 February 1999) and can be framed against global saffron supply, where FAO notes that Iran accounts for over 90% of world production—highlighting that Greek distinctiveness is primarily value/quality- and origin-based rather than volume-based [115–117]. In this setting, compositional standards (e.g., ISO 3632-1:2025 for saffron) provide a globally legible quality language through which place-based Greek products can communicate distinctiveness in international markets [118]. Local institutional narratives also emphasize the labor-intensive harvesting and long historical embedding of Kozani saffron in the region, further reinforcing the "place" component of distinctiveness beyond chemistry alone [119].

Biodiversity and conservation baselines strong foundations, actionable gaps. Building on this hotspot framing, the review confirms Greece as a regional plant-diversity hotspot, with MAP rich families (notably Lamiaceae) disproportionately represented in endemic and culturally salient taxa (e.g., *Sideritis* sp., *Origanum* sp., *Thymbra* sp., *Salvia* sp.) [1–5]. Contemporary floristic syntheses and portals (e.g., Vascular Plants of Greece and the Flora of Greece web portal) anchor a robust taxonomic and distributional baseline [4,5], complemented by the spatial policy scaffolding of Natura 2000 and Greece's PAF 2021–2027 [6,120,121]. Yet climate and land-use change remain material pressures at the Mediterranean scale, as the region is widely recognized as a biodiversity hotspot under increasing threat [1,2]. For Greek MAPs, climate-change dependence analyses that inform ex situ conservation planning illustrated by recent work on wild medicinal plants in Crete underscore the need to integrate environmental change into management and sourcing decisions [11]. Additional floristic and risk resources such as the Atlas of the Aegean Flora and the European Red List of Medicinal Plants sharpen prioritization for endemic and island taxa and indicate where in situ protection should be paired with cultivation and germplasm conservation to relieve pressure on wild stands [122,123]. Together, these layers suggest an actionable conservation agenda: protect and monitor habitats where *Sideritis* sp. and other endemics overlap with high tourism/land-use pressure; develop ex situ and seed-bank pipelines tailored to provenance and chemotype; and use distribution/suitability models to climate-proof ("future-proof") sourcing and restoration planning [11,122,123].

9.1. Ethnobotany and Socio-Economic Linkages—Living Knowledge with Place-Based Leverage

Ethnobotanical knowledge remains vibrant but spatially heterogeneous, with mainland and island repertoires reflecting biogeographic structure and market integration [31–33]. Case studies from Central Macedonia and the Thessaloniki herbal market show continuity and adaptation of uses, and how traditional knowledge flows into urban trade [31,32]. Place-based products translate biocultural heritage into traceable value: Chios mastic (UNESCO Intangible Cultural Heritage; EMA monograph) and Krokos Kozanis saffron (EU PDO) demonstrate that legally recognized origin and practice can underpin premium markets provided quality and provenance are safeguarded [93,94]. These findings support targeted "conservation-through-use" investments in flagship taxa that are simultaneously biodiversity-relevant, culturally salient, and market-viable.

9.2. Phytochemistry and Bioactivity Rich Chemistry, Uneven Clinical Translation

Flagship Greek MAPs exhibit well-documented chemical diversity with promising biological signals. The Sideritis complex (Greek mountain teas) shows polyphenol/terpenoid richness and neurocognitive/anti-amyloid signals in preclinical models, with a randomized trial reporting acute and chronic effects on cognition and cerebral blood flow for *S. scardica* extract [27,90–92,124]. HMPC's EU monograph for Sideritis herba links traditional uses to quality specifications, strengthening the path from field to finished products [125]. *Origanum vulgare* subsp. *hirtum* (Greek oregano) and *T. capitata* are typically carvacrol/thymol-rich, with broad antimicrobial/antioxidant and bioherbicidal profiles pertinent to "green" bioprotection and food biopreservation [95,97,98]. *Salvia fruticosa* (Greek sage) displays geographic/altitudinal chemovariation (often 1,8-cineole–rich), highlighting the importance of provenance in meeting pharmacopoeial and safety expectations [99,100]. Notably, while phytochemical and preclinical evidence is abundant, translational evidence remains uneven; beyond *Sideritis* sp., few taxa have standardized, adequately powered human studies. This argues for harmonized extract specifications, chemotype-provenance documentation, and staged clinical/real-world evidence pipelines for priority taxa [19,27,90–92].

9.3. Quality, Authenticity, and Sustainability Standards—Linking Field Practice to Market Trust

Upstream practice is central to both quality and conservation. WHO/FAO GACP guidance and the 2025 HMPC Revision 1 of the EU GACP Guideline provide aligned expectations from cultivation/wild collection through primary processing [126–128]. For wild-collected taxa, FairWild operationalizes ecological and social criteria harvest rotations/quotas, minimum cutting heights, community monitoring, traceability, and fair benefit-sharing directly applicable to Greek MAP landscapes [129,130]. On the regulatory front, EMA monographs (e.g., Sideritis herba; mastic) and PDO/PGI/UNESCO recognitions (e.g., Krokos Kozanis; Chios mastic) add compliance and origin-of-quality anchors [94,101,131,132]. Where EU herbal monographs are absent as for *S. fruticosa* HMPC Public Statements/Assessment Reports and ESCOP monographs should guide claims and specifications; conversely, Thymi herba (for *Thymus* sp.) provides an established EU benchmark [133–135]. Beyond herbs as medicines/foods, sectoral approvals (e.g., EFSA opinions for oregano EO as a sensory feed additive and related EU implementing acts) broaden legal pathways for safe, value-added use [133,135].

Authentication remains a systemic challenge especially for oregano in global trade. Multi-modal toolkits combining vibrational spectroscopy and high-resolution mass spectrometry with DNA-based methods (NGS metabarcoding; ddPCR) and NMR have shown high accuracy in detecting and quantifying botanical adulteration; integrating such tests at intake can materially reduce fraud risk and protect Greek origin claims [136–138]. Quality control (WHO) and Good Herbal Processing (GHP) guidelines complement GACP by addressing analytical and handling steps that shape chemical integrity [139,140]. Finally, ABS/Nagoya compliance (EU Reg. 511/2014 and Implementing Reg. 2015/1866) and Greece's National Biodiversity Strategy provide the legal architecture for access, benefit-sharing, and protection of traditional knowledge across research and commercial pipelines [102–104].

9.4. Evidence Gaps and Methodological Considerations—What Limits Inference Today

By design, this is a scoping (mapping) synthesis rather than a quantitative meta-analysis, reflecting heterogeneity in aims, methods, and outcomes across included records [12,13,15]. Ethnobotanical studies are often local/small-n and liable to recall/selection effects; market snapshots (e.g., 2004) may not reflect current patterns [32,33]. Phytochemical studies vary in extraction protocols, GC–MS settings, and post-harvest handling, complicating comparability. Many biological studies remain preclinical, and standardization of extract specifications is uneven, limiting translatability [27,90–92,100,124]. Climate projections and land-use trajectories introduce uncertainty in habitat and cultivation planning, reinforcing the importance of scenario-based suitability modeling and adaptive management [1,2,11].

9.5. Implementation Priorities—Operational Steps for Greece

(1) Prioritize endemic Lamiaceae and other flagships (*Sideritis* sp., *O. dictamnus*, *T. capitata*) for domestication and cultivation, with seed-banking (via Greek Gene Bank/ELGO-DIMITRA) [141], ex situ trials across climate gradients, and chemotype stabilization/pre-breeding to relieve wild-harvest pressure aligned with ECPGR MAP Working Group coordination [11,28,105,141,142].

(2) Institutionalize GACP on farms and FairWild in wild-collection zones, co-developing practical field protocols (harvest calendars, rotation, quotas, minimum cutting heights) and community-based monitoring aligned with buyer specifications [8,126,127].

(3) Upgrade traceability and authenticity controls via batch-level "digital lot passports" that link provenance, chemotype, and ABS documentation, and embed multi-modal authentication (spectroscopy + HRMS + NGS/ddPCR/NMR) at intake for high-risk botanicals (e.g., oregano) [136–138].

(4) Plan for climate resilience by coupling species-distribution and suitability models with site selection, germplasm sourcing, and adaptive harvest calendars; use ex situ suitability forecasts to guide landscape-level planting [1,2,11].
(5) Build an open, FAIR data backbone connecting occurrence/voucher records, GC–MS/LC–MS profiles, ethnobotanical uses, and value-chain metadata, with persistent identifiers and provenance fields to support compliance and reproducibility [5,143].
(6) Strengthen ethical and legal partnerships with knowledge holders under ISE ethics and ABS/Nagoya, ensuring prior informed consent, equitable benefit-sharing, and protection of traditional knowledge [144–148].
(7) Leverage origin-of-quality schemes and sectoral standards, including PDO/PGI and ISO specifications (e.g., saffron ISO 3632-1:2025), to reward stewardship and anchor premium markets [94,118,132,147,148].

10. Conclusions

This PRISMA-guided scoping review (2000–2025; final N = 148) integrates biodiversity, ethnobotany, phytochemistry/biological activity, and policy/standards to provide a consolidated picture of Greek medicinal and aromatic plants (MAPs) in their Mediterranean context. Greece's Lamiaceae-rich flora featuring endemic and culturally emblematic taxa such as *Sideritis* sp., *O. vulgare* subsp. *hirtum*, *T. capitata* and *S. fruticosa* anchors living knowledge systems and active value chains while offering scientifically grounded avenues for sustainable use. Place-based products like Chios mastic and Krokos Kozanis illustrate how biocultural heritage can translate into traceable, high-value markets when quality and provenance are safeguarded.

At the same time, accelerating climate and land-use change, local overharvesting pressures, and methodological heterogeneity across studies underscore the need for deliberate, evidence-based management. The enabling toolbox is already substantial: Natura 2000 and the national Prioritized Action Framework (PAF) set the spatial policy frame.; EMA/HMPC monographs and the revised EU GACP guideline codify quality and upstream practices; FairWild provides a pathway for responsible wild collection; PDO/PGI and UNESCO recognitions reward origin, craft, and stewardship; and ABS/Nagoya ensures lawful, equitable access and benefit-sharing.

The priority is now operationalization. We identify six cross-cutting actions that can convert potential into outcomes:

Conservation-through-use of priority endemics. Fast-track domestication, ex situ support, and provenance/chemotype stabilization for flagship taxa to relieve pressure on wild stands while preserving genetic diversity.

Standards at scale. Embed GACP on farms and FairWild in wild-collection areas via training, quotas/rotation, and community-based monitoring, with buyer-aligned specifications.

Traceability and quality assurance. Link chemotype to provenance through batch-level documentation and digital lot passports to meet regulatory, market, and ABS requirements.

Climate resilience. Use species distribution and suitability models to guide siting, germplasm sourcing, and adaptive harvest calendars; integrate risk into regional planning.

Open, FAIR data infrastructure. Connect occurrence/voucher records, GC–MS/LC–MS profiles, ethnobotanical uses, and value-chain metadata to support reproducibility, policy, and trade.

Biocultural partnerships and equity. Formalize collaborations with knowledge holders and producer groups so that benefits are fairly shared and practices remain culturally grounded.

If implemented, this agenda can safeguard habitats and knowledge systems, raise product quality and market confidence, and generate resilient rural livelihoods. By aligning conservation goals with rigorous standards and transparent value chains, Greece can position its MAP sector as a Mediterranean exemplar one where biodiversity stewardship, biocultural heritage, and a modern, traceable bioeconomy move in step.

11. Future Perspectives

This scoping review highlights a tractable agenda for aligning biodiversity conservation with rural development via Greek medicinal and aromatic plants (MAPs). Below we outline forward-looking, actionable priorities to guide research, policy and practice over the next 5–10 years.

Data infrastructure and FAIR integration. Build a nationally coordinated, FAIR-compliant knowledge graph that links occurrence data (including Natura 2000 layers), voucher/barcode records, chemotype profiles (GC-MS/LC-MS), ethnobotanical use records, and value-chain metadata. Prioritize persistent identifiers (DOIs) and provenance fields to ensure traceability and reproducibility.

Standardized methods and monitoring. Co-develop (with collectors and SMEs) harmonized field protocols for sustainable wild collection (harvest quotas, rotation, minimum cutting heights, reproductive safeguards) and community-based monitoring. Deploy remote sensing and high-frequency phenology cameras to track habitat condition and harvest pressure; pilot eDNA for population monitoring of rare endemics.

Genetics, domestication and breeding. Fast-track domestication of priority endemics (e.g., Lamiaceae flagships) via seed banking, ex situ trials across elevation/climate gradients, chemotype stabilization, and marker-assisted selection. Establish pre-breeding pipelines for drought/heat tolerance, pollinator-positive traits, and pathogen resistance; explore micropropagation for difficult taxa.

Agroecology for MAP cultivation. Design intercropping and regenerative systems that maintain soil function and water-use efficiency, while enhancing pollinators. Set up a distributed network of living labs (islands, mountains, semi-arid lowlands) to test management packages (organic/GACP-compliant) and quantify ecosystem-service co-benefits.

Climate adaptation and risk. Couple high-resolution species distribution models with climate/land-use scenarios to identify resilient refugia and future cultivation zones; pilot assisted gene flow where appropriate. Integrate climate risk into regional plans and producer insurance schemes; create drought early-warning triggers for harvest closures.

Quality assurance and regulation. Operationalize EMA/HMPC monographs and the revised EU GACP guideline along the full chain (from seed to shelf). Adopt chemotype-provenance certificates and batch-level traceability (digital lot passports) to meet buyer specifications and ABS/Nagoya compliance. Scale FairWild certification for wild-collected taxa.

Value-chain innovation and circularity. Promote SME clustering around green extraction, solvent recycling, and valorization of by-products (spent biomass to biostimulants/biopesticides). Use life-cycle assessment (LCA) to benchmark environmental footprints; expand PDO/PGI/UNESCO-style recognitions where culturally and scientifically justified.

Ethics, ABS and biocultural partnerships. Mainstream community protocols and equitable benefit-sharing agreements; ensure prior informed consent and protection of traditional knowledge. Build practical guidance for researchers and firms working under the EU ABS framework and the Nagoya Protocol.

Translational and clinical research. For flagship taxa (e.g., S. scardica complex), progress from phytochemical/biological evidence to well-powered, standardized clinical trials and pharmacoepidemiology, with robust safety and interaction monitoring. Align finished-product specifications with monograph standards.

Funding, training and capacity. Leverage European instruments (e.g., Horizon Europe, LIFE, Interreg MED) and national programs to support living labs, breeder–collector–SME consortia, and training for GACP/Fair Wild. Invest in extension services for collectors and smallholders, including digital tools for field data capture.

Monitoring and evaluation. Set clear key performance indicators (KPIs) for monitoring conservation status, harvest compliance, product quality, climate resilience, and socio-economic factors like employment and equity. Report these KPIs yearly and adjust management strategies as needed through adaptive management cycles.

Overall, these future perspectives outline a practical roadmap for Greece to establish MAPs as a leading center where biodiversity conservation, biocultural heritage, and a resilient, traceable bioeconomy develop together.

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Abbreviations

The following abbreviations are used in this manuscript:

MAPs	Medicinal and Aromatic Plants
GACP	Good Agricultural and Collection Practices (WHO/FAO; EMA/HMPC)
EMA/HMPC	European Medicines Agency/Committee on Herbal Medicinal Products
ABS/Nagoya Protocol	Access and Benefit-Sharing framework under the Convention on Biological Diversity
PDO/PGI	Protected Designation of Origin/Protected Geographical Indication
FairWild	Standard and certification scheme for sustainable wild collection of plant ingredients
Natura 2000	EU network of protected areas; PAF is the Prioritised Action Framework for funding/implementation
EO	Essential oil

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