Ecosystem Services Potential of Endemic Floras

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Natural, sustainable products arise in many fields, wild plants are reconsidered as providers of traditional or innovative applications. The notion of ecosystem services (ES) provides a frame to evaluate their benefits, but is still scarcely applied to endemic floras.

biodiversity management | Greek flora | knowledge gaps | medicinal plants

1. Introduction

Facing an increasing pressure on fossil resources and a multiplication of biological, ecological and social issues (e.g., microbial resistance, long term health effects, pollution, work conditions, etc.), Western societies progressively consider natural resources as a solution for their ever-growing needs in energy, food, materials and drugs [1][2][3]. Previously left aside to the benefit of synthetic substances, plant products are now envisaged as the answers to the current demand in a local, environmental-friendly production [4][5]. As the World Health Organization itself recognizes the value of traditional and complementary medicines, phytotherapy, homeopathy, aromatherapy and naturopathy appear to be considered more often as alternatives to conventional medicine, and ethnobotany and ethnopharmacology emerge in biological sciences to re-discover ancient practices and to protect their endangered wisdom [6][7][8][9][10].

Greece has a role to play in this mutation of medicine. Rich in its millennial history, the country has left a significant print on medicine, with, for instance, herbalists such as Theophrastus and Dioscorides, who gathered a significant anthology of the medicinal plants' uses of their era [11][12]. Its natural richness is also a major asset of this Mediterranean country: covering about 7000 plant species, including more than 1400 endemic taxa [13][14][15], Greece is one of the most important plant diversity hotspots in Europe [16]. This multiplicity contributes to the bound between its history and its landscapes, as it provides, now as before, a wide array of ecosystem services [17].

Ecosystem services (ES) could be defined as 'the aspects of ecosystems utilized (actively or passively) to induce human well-being', linked to the basic ecology of the ecosystem (e.g., soil depollution, host for other species, flooding containment, etc.) or to the uses humankind make of it (e.g., food, wood, cultural or spirituals involvements, etc.) [18]. This notion underlines the strong bond between biodiversity and human activities and needs, acknowledging the value of taxa that will allow the subsistence and development of the species. It becomes a tool to argue with stakeholders on the necessity of environmental policies to preserve this bond [19][20]. With its outstanding biodiversity, Greece is considered one of the regions where medicinal and aromatic plants-major ES providers-constitute an important natural resource [21].

Greek and worldwide research teams have acknowledged this pit of diversity by leading numerous investigations on ecological, taxonomical, genetical or botanical aspects on the countries' flora [14][22][23]. The studies on the endemic species of Greece are nonetheless still punctual and uncomplete, particularly regarding the ES these taxa could provide [24]. In the context of the Mapping and Assessment of Ecosystems and their Services (MAES) [25] implementation in Greece, and in the frame of the currently in progress Flora of Greece Web project, the goals are to analyze the knowledge already acquired on ES offered by the endemic flora of Greece and to expose its potential for further ES, with a local focus on the floristic region of Peloponnese (SW Greece).

2. A wide Diversity Accurate to Greek Flora

With 494 endemic taxa, Peloponnese presents the highest number of Greek endemic taxa for a region in Greece. On a previous edition of the Vascular Plants of Greece [14][15], as its list only counted 468 endemic taxa, Peloponnese had the most important proportion of endemic species and subspecies in terms of total number of taxa and the second most important endemism rate (percentage of endemic taxa within the flora of a region) after the Kiklades (Cyclades) (14.6% for Peloponnese against 17.6% for Kiklades).

The content of its diversity is in agreement with the endemic flora of Greece as presented by Dimopoulos et al.: the genera with the most endemic taxa are for both Greece and Peloponnese *Limonium* (79 taxa in Greece and 15 in Peloponnese), *Centaurea* (76 and 17), *Hieracium* (73 and 20), *Campanula* (60 and 17) and *Silene* (53 and 21).

The pattern concerning the habitats rich in endemic species is equally similar between Greece and Peloponnese scales. The most frequent habitats are, for both, either cliffs, high mountains or phrygana.

The diversity of the endemic flora is also figured by the diversity in the essential oil compositions of the tested taxa: from 73 samples of 39 endemic taxa provided with full analysis, 38 first components have been extracted. The main ones, as carvacrol and thymol, have already been specified for their high medical interest, for applications such as antimicrobial, antioxidant or anticancer [26][27].

The significant number of countries (36 countries) involved in the investigation of the Greek endemic flora present in Peloponnese highlights the importance of its endemic species for genetic, phytochemical and taxonomical stakes.

3. Gaps in the Knowledge of This Diversity

Despite its acknowledged scientific interest, the endemic flora of Peloponnese remains widely understudied for its ecosystem services. The average number of articles per taxon is 0.52 (including properties, status and genetic), whereas it reaches 1.37 for the full list of taxonomy relatives and 1.76 for the full list of phylogeny relatives. If the available data on some rare species reveals to be highly restricted (seven taxa with no search results on Google Scholar, 21 taxa with only one hit), the most striking figure relies on the 372 taxa that have not been studied for their ecosystem services yet, representing 75.3% of the endemic flora of the region. The lack of information also extends to the risk status which remains unevaluated or data deficient for 85.7% of this restricted flora.

In addition to this gap in terms of quantity of investigated endemics, an imbalance is visible on the repartition of the research effort among the different families. This effort is particularly concentrated on Lamiaceae and Asteraceae taxa; both these families representing 27.9% of the endemic taxa with documented ecosystem services and 64.1% of the taxa with full essential oil composition described. The interest in these two families is legitimated by traditional and medical uses as well as by their proportion among the endemic flora, the easy extraction of their essential oils and an abundant scientific background on the properties of their more common species. It should, however, not obstruct the high potential of rare taxa from other families. The discrepancy also shows in the variety of phylogenetic studies, as 15 families out of 49 (30.6%) are not provided with phylogenetic investigations, and are thus deprived of phylogenetic relatives in the context of this article (e.g., Alliaceae, Globulariaceae, Polygalaceae, Rutaceae, etc.).

The diversity of documented properties is another subject of imbalance, at the scale of a genus as well as at the scale of the whole endemic flora. The environmental benefits are the most frequently quoted properties for the endemic taxa (71 taxa). There is nonetheless a proportion of these benefits that relies on the observation of punctual and indirect assets for aesthetic and educational purposes, such as the display in a botanical garden (17 taxa) or presence on a historical site (16 taxa). For the medicinal properties, priority is given to antimicrobial or antioxidant applications which require well-defined and accessible in vitro protocols, leaving aside uses such as skin care or gastrointestinal treatments, for instance, which would require in vivo or at least more complicated experiments to set.

The small number of taxa investigated for their full essential oil composition confines the knowledge on the benefits of the essential oils, as the documented ones prove not only to contain molecules of interest, but also to develop them at high concentrations (*Thymus leucospermus* with carvacrol and thymol; *Paeonia mascula* subsp. *hellenica* with salicylaldehyde, a compound that once derived can have antibacterial, antitumor or fluorescence properties) [28][29].

As mentioned by Cheminal et al. [24], the reasons for these gaps of knowledge can be various, e.g.,

- Complicated access to the natural habitat of the species and localization of the growth spot,
- Limited plant material for small populations, which limits both the quantity of analysis and the potential ulterior applications,
- Limited productivity in essential oils for several families,
- Lack of relevance in the scientific context of one laboratory,

- Lack of time, workforce and funds,
- Lack of appeal for families with no well-acknowledged properties, etc.

4. Evaluating the Potential of Endemic Plants through Related Taxa

The review on the taxonomic or phylogenetic bounds between endemic and non-endemic taxa is used formally for the first time in the analysis of endemic flora's ecosystem services. It allowed to considerably widen the scope of the study. Associating these related taxa to their endemic cousins permitted to suggest additional properties for 88 endemics based on taxonomy and 103 endemics based on phylogeny, leading to a total of 154 taxa with completed properties potential. The number of potential applications improves in quality and in quantity, with the number of properties categories per taxon jumping from 0.37, without the addition of relatives' data, to 1.12 after, including some 65 uses that have not yet been studied for endemic taxa, such as treatment in case of mental disorders, fever or bladder issues. Some precaution needs to be taken for the 'Traditional medicine' and 'Environmental benefit' categories being tightly dependent to the spatially limited knowledge of local inhabitants or to punctual presence in gardens or historical sites, and thus being less 'extensible' properties from non-endemics to endemics.

Moreover, the addition of this dataset suggests other chemical composition patterns, with main components such as 2-undecanone or (E)-beta-farnesene, that have not been found among endemic taxa yet. These two components have been extracted from Rutaceae and Apiaceae taxa, whereas most of the endemic taxa analyzed belong to Lamiaceae and Asteraceae. A wider range of investigated families would then allow to discover more diverse chemicals of interest, in concentrations that may prove of use for their production.

Practically, if the investigation of related taxa can bring a denser and more diverse array of properties suggestions, it also shares the research effort with multiple research teams, study specialties and countries, evolving from 36 countries invested on the study of Greek endemics of Peloponnese to 83 countries mentioning their relatives. This helps to buffer the low amount of data targeting endemic species and to enlarge the evaluation of their potential.

Nevertheless, for chemicals as well as for properties, the extension of non-endemic datasets as relevant to endemic taxa only leads to the definition of characteristics that become more likely to be discovered in the concerned taxa. As chemicals and properties are not only dependent upon genetics and taxonomy but also on environmental conditions (i.e., climate, soil, light, disturbance, season, etc.), the purpose of this part of the article is not to conclude on the effective presence of properties in taxa, but to nominate some taxa as of priority for further studies. Researchers therefore highlight the following taxa as the ones presenting either/both the higher number of relatives with properties, of suggested property categories or of total weight in terms of articles for their relatives: *Achillea taygetea* and *Anthemis cretica* subsp. *panachaica* (Asteraceae), *Rindera graeca* (Boraginaceae), *Lonicera alpigena* subsp. *hellenica* (Caprifoliaceae), *Centaurium erythraea* subsp. *limoniiforme* (Gentianaceae), *Crocus biflorus* subsp. *melantherus* (Iridaceae), *Ballota* *nigra* subsp. *anomala, Lamium garganicum* subsp. *pictum, Sideritis clandestina* and its two subspecies *clandestina* and *peloponnesiaca* (Lamiaceae), *Abies cephalonica* (Pinaceae), *Nigella arvensis* subsp. *brevifolia* and subsp. *aristata* (Ranunculaceae).

Noticeably, even with the addition of this dataset, the gaps of knowledge are still visible; especially concerning some families that have a contrast between a considerable number of endemic taxa but a low number of documented properties: Campanulaceae (18 endemic taxa, three documented for their own environmental properties, and three by extended properties), Plumbaginaceae (15 endemic taxa, four documented for their own environmental properties, and one by extended properties), Alliaceae (14 taxa, one with documented properties and one with supposed environmental interest), Poaceae (11 taxa, only one with extended properties) or Colchicaceae (six taxa, only one with own supposed ornamental interest). Nine families of smaller sizes are deprived of properties even with the extension: Aceraceae, Convolvulaceae, Fumariaceae, Isoetaceae, Linaceae, Orobanchaceae, Polygalaceae, Resedaceae, Saxifragaceae.

5. Stakes and Clues for the Protection of Important Flora

The vast majority of the Greek endemic plant taxa is considered under threat in general, while the mountain massifs of Peloponnese are rendered as threatened Greek endemic hotspots [30]. Based on the results of the study, the current extent of the Natura 2000 network seems to provide a concrete protection scheme for the Greek endemics of Peloponnese, safeguarding simultaneously the ES that they provide or could potentially provide. However, concrete measures and actions should be integrated for MAPs in the current protection scheme by the -under development- Special Environmental Studies for the Natura 2000 sites of Peloponnese, that propose protection zones within each Natura 2000 sites, where specific actions and projects will be allowed [31]. Moreover, identification, current assessment and thematic mapping of MAPs' and relevant ES' hotspots support the national efforts for the MAES implementation in Greece [17] and provide baseline data for relevant indicator development.

In order to provide a new tool for the protection of endemic flora, the present method adding non-endemic relatives to the endemic knowledge could be formalized into an indicator. With the goal of evaluating the ESP potential of under-documented taxa, this literature-based indicator could be an accessible and numbered argument in favor of the protection of ES-rich areas or of rare MAP taxa, reinforcing the current conservation processes.

6. Implications for Sustainable Rural Management

Based on the results of the study, the components, properties, and the unique genetic resources that render the profile of the endemic MAPs a valuable, natural resource for a variety of ES, points out their importance as a well-being element of the countryside. Already in the Peloponnese, endemic MAPs are under collection threat in the wild and relevant monitoring programs are ongoing by the Greek authorities (personal communication with the Management Unit of Chelmos-Vouraikos National Park and the protected areas of north Peloponnese). Moreover, their importance as valuable ES is recently rendered by the field-based assessment for local scale MAES implementation at the National Park of Chelmos-Vouraikos, by Tsakiri et al. [32]. By this, it is evident that MAPs are an integral part of rural practice, supporting traditional uses, local, agricultural income and needs [24][33]. However, the added value that can be provided by Greek and local (e.g., Peloponnesian) endemics should be taken into account in the agricultural practice and the national agricultural strategy, since the provisions of the European Green Deal [34] support biodiversity sustainable agricultural products and schemes. Practice can be developed by identifying suitable areas for endemic MAPs cultivation, using habitat suitability models (e.g., [35]) and suggest their being priority sites for MAP cultivations and/or for agro-tourism, thematic parks. By this, MAPs will be sustainably exploited as a unique and important part of the natural capital of Greece.

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