

Article

# On the Biogeographical Significance of Protected Forest Areas in Southern Romania

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**Abstract:** The current study is seeking to highlight the biogeographical significance of the protected areas located in southern Romania, a territory continuously exposed to strong human pressure since early times (e.g., extensive/intensive agricultural use, industrialization, urbanization/suburbanization processes). As a result, the primeval vegetation has been massively transformed and forests have been significantly fragmented and reduced to even smaller surfaces (e.g., Călăraşi County has the smallest forest-covered area in Romania). Under these conditions, the current forest patches have suffered important floristic and faunistic structural changes. Some forest remnants have been assigned protected areas status of biogeographical significance, as they host and preserve valuable southern arboreta species and xerothermal associations, secular and multi-secular arboreta (even some virgin arboreta), relict, endemic or unique species, or having their world biological limit. To stress the biogeographical significance of the forest protected areas, the authors carried out in-depth investigations of the ecosystem structure focusing on the spatial and statistical changes occurring over recent centuries and the key phyto- and zoological elements relied on the cross-referencing the biological, biogeographical, and geographical scientific literature and on the reviewing of the historical data sources. The study provides a comprehensive analysis of the biogeographical elements based on selected indicative taxa (*Quercus* species) and witness species considered important for southern Romania, which were able to reconstruct the original ecosystems to explain and understand their significance for the preservation of the current ecosystems.

**Keywords:** protected forest reserves; biogeographical significance; Romanian Danube Plain

## 1. Introduction

Under increased and diversified population pressures, the human influence on forests in Europe is progressively increasing [1]. Past and present pressures on forest resources have led to significant changes in its structure, composition, and dynamics, and to severe decrease in the surface of unmanaged or poorly managed forests [2], ultimately leading to biodiversity loss and habitat fragmentation. In Europe, protected forest areas account for about 12% of the forest area. However, about 70% of the mostly semi-natural forest area is targeted for multi-purpose use and is located outside designated protected forest areas [1], thus requiring effective measures for protection and effective management. The Goals for European Forests and the European 2020 Targets for Forests had placed sustainable forest management (SFM) in the center of its objectives which is to be monitored through key indicators [3]. Generally, apart from Northern Europe and mountainous regions, forest areas are highly fragmented by roads and railway systems, often becoming patches surrounded by agricultural land and urban areas [1].

The general deep history of forest transformation in Europe begun with the agricultural and settlements expansion under the growing demand for food, fiber and living space which have led to forest fragmentation and even deforestation on certain surfaces. As a result, the main concerns of the forest landscapes at European level are related to changes in patterns, fragmentation, and connectivity under the continuous expansion of agricultural areas, transport infrastructures, settlements, and fire occurrence [4]. Central and Eastern Europe states, in particular, have undergone drastic socio-economic and political changes since 1990 (after the fall of communism) when socialistic state economies transitioned toward market economies bringing in extensive land use transformations, including forest fragmentation and forest cover changes [5,6]. Forests provide important ecosystem services, and protected areas (e.g., national parks, nature reserves) play an important role in reducing human disturbance on forests and protecting ecosystems and species which are unlikely to survive in intensively modified areas [5,7]. Protected forest areas are particularly important since they help maintaining biodiversity through two complementary aspects: important protection sites, covering rare, vulnerable, and valuable forest ecosystems and applying nature-based silviculture in the remaining production forests [8]. Forest disturbance differ among Central and East European countries depending on the diversity of human pressures and effectiveness of forest management. In some countries (e.g., Poland, Slovakia) the success of protected areas proved to be higher, thus harvesting rates dropped noticeably after protected areas were designated, leading to reduced forest fragmentation [5]. In Romania, environmental policies were not always able to provide protection for forests for being fragmented or even logged. Thus, under the socio-economic or institutional changes of the last decades, the effectiveness of protected areas was often affected, and significant deforested areas have been recorded [9–11]. Thus, forests constantly shrank, especially on the privately-owned terrains, under land privatization, changes in forest use regulations or forest restitution [12,13] leading to loss of species that have biogeographical or conservation significance for ecosystem functioning.

In Romania, protected forest areas-related issues were mainly addressed through the structural and functional transformations of the forest cover in general, under the influence of different political and socio-economic events, i.e., land reforms [6,10,14,15] using geospatial analyses at large (national or the Carpathian Chain) [16–18] or small-scale [19–21]. In addition, some studies focused on the conservation of forests [20,22] and their management in protected areas [11,23,24], as well as on forest degradation under extreme weather events and pollution [25,26]. Nonetheless, there is an increasing need to focus more on the protection of forest protected areas, especially in areas under the growing human influence, i.e., Southern Romania.

## 2. Study Area

The current study focuses on six counties (Constanța, Călărași, Giurgiu, Teleorman, Olt and Dolj) which lay in the south of Romania and overlap plain and low tableland relief forms (under 400 m alt.). The intense human pressure, the southern part of Romania was exposed to since early time, is visible in the large deforested areas that place these counties among the poorest wood-covered territories in this country today (Călărași—4.3%, Teleorman—5.0%, Constanța—5.7%, Olt—10.7%, Giurgiu—10.8% and Dolj—11.5%). However, these counties still preserve some species of flora and fauna reaching the limit of their geographic distribution in Europe [27–30]. From physical-geographical point of view, the study area largely falls into two main relief forms unfolding in the southern Romania: Romanian Plain and Dobrogea Plateau.

The southern part of Romania is characterized by distinctive biogeographical features due to the complex interaction of Central-European forest with Pontic, Steppe and Submediterranean biogeographical elements (with some outstanding Balkan or Balkan-Pontic species) (Figure 1).

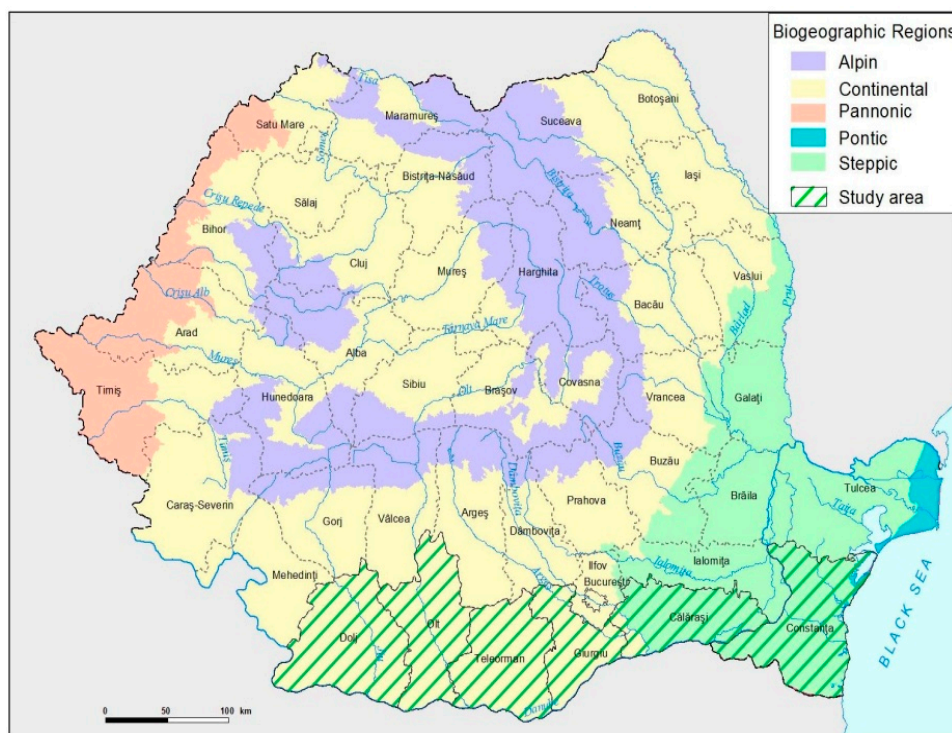


Figure 1. Biogeographical Regions in Romania and the position of the study area in Romania.

Nevertheless, natural vegetation has been replaced by agroecosystems over extended areas thus affecting the integrity and continuity of these valuable vegetation complexes [31,32]. Forest shrinkage had seriously affected land quality by way of heavy rainfall, erosion, landslides, and the intensification of extreme weather events (e.g., floods, snowstorms, and droughts). Moreover, the climate change-related extremes, coupled with the destruction of the irrigation systems and the cutting of protection forest belts (wind breaks) have influenced the frequency and length of dry periods with negative effects on crop production, environment and living conditions [15,33]. However, as of the year 2000, through extending the surface of natural areas under protection, deforestation practices diminished within their boundaries protected areas boundaries. This region is crossed by an important biogeographical limit: the steppe vegetation that characterizes the eastern part of Europe and the mesophyllous deciduous forests, specific to Central Europe. At the contact between these two major units lies the sylvo-steppe zone, as strip varying in width that stretches between the Romanian Plain (in its southern and eastern parts) and in small areas eastwards, in Dobrogea (Figure 2).

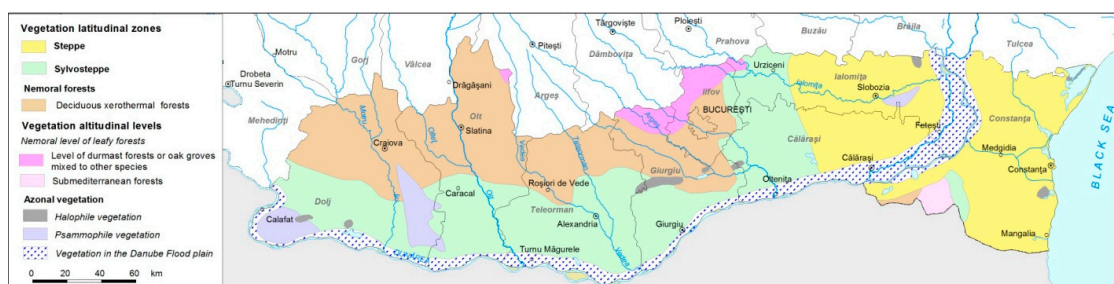


Figure 2. The spatial distribution of vegetation zones and altitude belts in the study area (processed after [34]).

Another particular feature of the vegetation cover is the presence of some species of Mediterranean origin in the south-western part of the Romanian Plain and in Dobrogea [32,35]. Moreover, the relatively

small differences in terms of altitude, slope, and lithology (e.g., loess, sand, clay) is reflected in the structure and composition of the vegetation. In some areas (e.g., floodplains, subsidence plains), an important influence is exerted by the underground water table close to the surface which has led to a widespread of intra-zonal and azonal hygrophilous vegetation [36]. Thus, the forest vegetation spreads southwards along the main river floodplains, getting closer to the Danube Floodplain, south of Bucharest.

### 3. Materials and Methods

To highlight the biogeographical significance of the forest protected areas located in southern Romania, the authors carried out in-depth investigations of the forest ecosystem structure focusing on the spatial and statistical changes occurred over the last centuries and the key phyto- and zoological elements. The analysis involved several steps: (1) to assess the changes in the distribution and dynamics of forest ecosystems; (2) to identify indicative taxa and witness species to assess the (3) phytogeographical and (4) zoogeographical importance of forest ecosystems for the sustainable preservation of forest biodiversity.

The state of knowledge of species dynamics, loss and rediscovery is essential in understanding their role for ecosystem integrity [37], as well as its implications for the development of the current study. Hence, the analysis of the persistence of some valuable species or stands mainly relied on the cross-referencing the biological, biogeographical, and geographical scientific literature which provided significant information on species biogeographical importance and spatial distribution. The change in the distribution and dynamics of forest ecosystems was assessed based on the visual interpretation of the historical data sources (e.g., Specht Map-1790, Russian Map-1835, Satmari Map-1856/1864, Austro-Hungarian Map-1912), topographic maps (e.g., 1970, 1988/1989, 2008) and the Corine Land Cover database (2002, 2006, 2012). The visual interpretation of the forest-cover dynamics was performed by querying the geospatial data provided by the historical data sources. The comparative analysis of the historical maps helped identify the areas where forest areas have been withdrawn to understand the impacts on biodiversity and forest integrity. For some forest areas subject to intense spatial transformations throughout time, particular visual analysis and comparative assessment of the historical maps were conducted to highlight the changes in structure and pattern throughout time. As a result, quantitative statistics on the spatial and temporal dynamics of forest ecosystems have resulted.

Having in view the intensive human intervention in the forest areas (whose total surface has been continuously reduced), the authors have selected as indicative taxa for Southern Romania some *Quercus* species-key species in most forests in southern Romania in the past and main remnants of the primeval vegetation [27,38–40]. They were used as witness species (as individual trees, in pure associations or in association with other species) to restore the valuable stands and justify their phytogeographical significance for the present-day ecosystems. Their assessment in the current stands also helped explain some qualitative and quantitative features (e.g., coverage, size of the specimens or parcels which still included secular trees, vigor of their population). The authors have also considered the last “relict” areas of some forest associations (e.g., the association of *Quercus* with *Tilia*) which, within thousands of hectares, fit into the virgin forests category.

The phytogeographical significance of the forests has been established considering the identification and framing of the most significant species into specific phytogeographical categories or, eventually into the main phytogeographical associations based on the biogeographic literature yet correlated with the phytogeographical regions of Romania and the typology of the forest ecosystems. Hence, the authors used the scientific literature on the floristic and faunistic composition of forest ecosystems in southern Romania (e.g., occurrence and description of indicative species from the earliest records). The data obtained were confronted with the Red Lists of the different categories of floristic and faunistic elements and the annexes of the EU Habitats Directive to highlight their biogeographical significance. Subsequently, on-field research aimed at updating the information and the significance

of new aspects have been carried out. These have been taken place in a series of forests such as Seaca-Optășani and Reșca-Hotărani (Olt County), Ciornuleasa (Calarasi County), Hagieni and Esehioi (Constanța County), Comana (Giurgiu County).

That being so, the selected species were considered indicators of the former compact forests, some still existing as patches of different size and some being totally disappeared. Moreover, the presence of the southern xerothermic associations (both forestry and bushy), which are unique in Romania, were also taken into consideration as reference associations in understanding the phytogeographical significance of the former forest ecosystems under the continuous historical human impact. The field surveys revealed the presence of high altitude species preserved in some plain forests (e.g., *Fagus*) which also explained the importance of these forest associations in restoring valuable forest ecosystems. Other species identified on the field were then correlated with the phytogeographical categories established for the flora of Romania. The zoogeographical field observations were made with respect to the species found in several forest areas, as well as in terms of their biogeographical significance: living at the limit of their geographical area in Europe or worldwide, being the last individuals of some species etc. These data were also correlated with the zoogeographical framing of species existed in the scientific literature. The statistical data (forest records), provided by the Forest Divisions included in the study area, have contributed to the quantitative and qualitative assessment of the analyzed species and forest patches. Thus, based on the forest records, the authors were able to compare initial and current surfaces where certain valuable species were found, species occurrence and health status, the importance of the witness species for the persistence and continuation of the ecosystem they live in etc. In addition, field investigations were conducted during various time-intervals between 2004 and 2014 in several forest stands within several protected areas which allowed the authors to validate the gathered data and find new evidence regarding the persistence of species of biogeographical importance. The field investigations also helped verifying the occurrence and status of the species cited by the scientific literature and/or finding new ones. Some field surveys benefitted from the support of several Forest Divisions: Băneasa (Constanța County, Bolintin (Giurgiu County), Craiova (Dolj County), Caracal and Slatina (Olt County). The general methodological flow of the conceptual framework is synthesized in Figure 3.

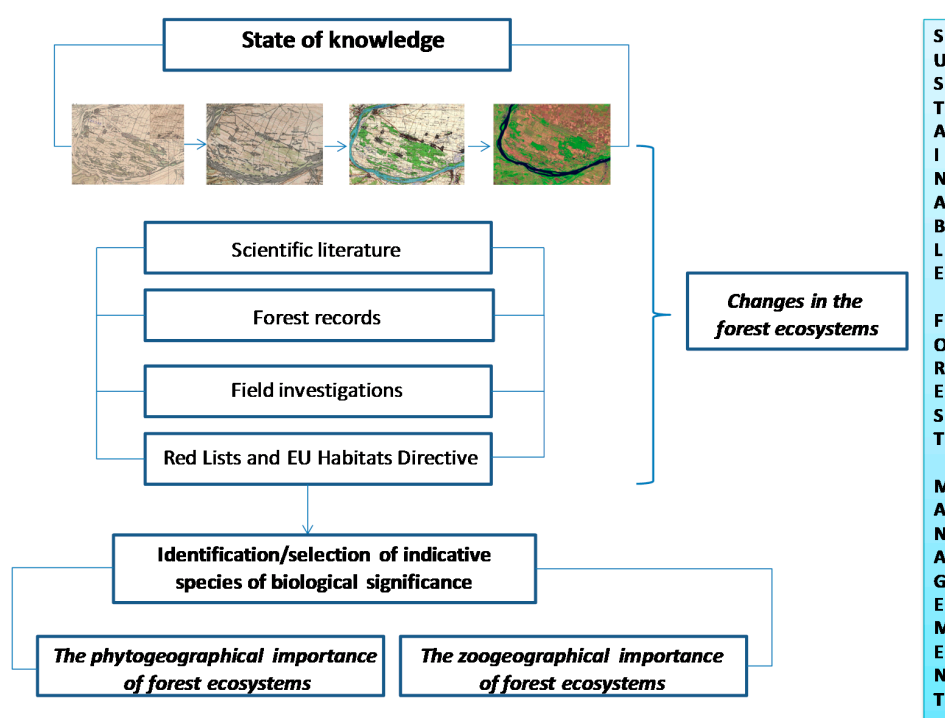


Figure 3. The general methodological flow of the conceptual framework.

The current study aims at providing a quantitative and qualitative overview of the forest ecosystems in one of the most dynamic human-modified ecosystems in Romania, also preserving, in small- or medium-sized stands, a wide variety of floristic and faunistic elements of high biogeographical importance. As a result, the two-fold major objectives come-off: (1) to assess the spatial distribution pattern and dynamics of protected forests in relation to the regional biogeography and land use changes and (2) to assess species significance and distribution (using indicative taxa and witness species) in particular protected forests with specific role in the protection of forest ecosystems. Hence, the research is seeking to draw attention to the biogeographical importance and conservation of forest ecosystems in a territory affected by spatial transformations mainly in relation to land use/cover changes and extended urban habitat which poses significant pressures to natural and semi-natural ecosystems.

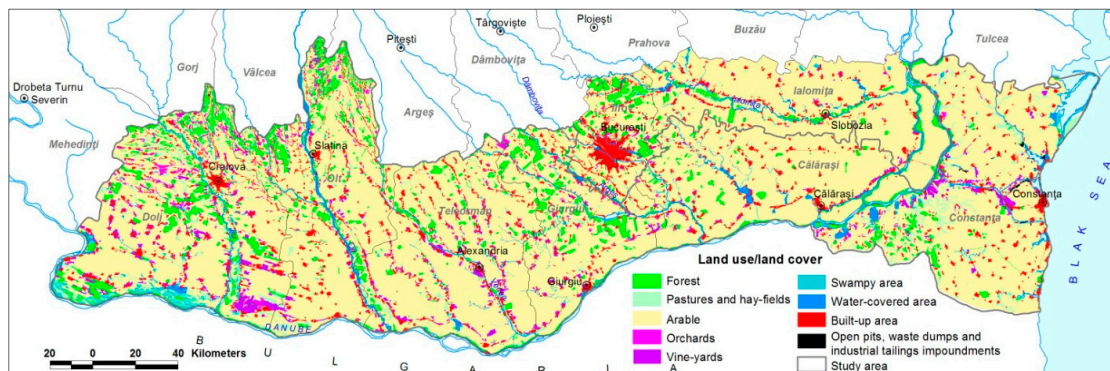
## 4. Results

### 4.1. Changes in the Forest Ecosystems

In southern Romania, the primeval vegetation has been massively transformed by human activity. Some vegetation types have contracted and almost disappeared, while others showed changes in their floristic structure and composition. Human-related activities have generally led to the expansion of xerophilous species at the expense of the mesophyllous elements. In many cases, the deforestation of the former zonal forest associations made room to secondary meadows (natural pastures and hay-fields), generally strongly degraded, and by agricultural crops [32]. Even where the forest vegetation has been preserved, its composition has been significantly modified by the recurring cuts at young ages, forest grazing, the selective extraction of some forest species, but also by the different regeneration capacity after cutting, the assortment of the wood species, the forest works and the tree planting after cutting-off [35]. In general, the rural-agricultural character of the study area has been enhanced during the 19th century, especially after the Treaty of Adrianople (1829) which brought in the freedom of trade (mostly cereals and timber) north of the Danube River. As a result, southern Romania witnessed a boosted development of agriculture and urban development which significantly and constantly impacted the forests. In some areas forests significantly shrank or even disappeared. Moreover, the continuous population growth and settlements development has led to the extension of agricultural land and access roads at the expense of forests. Hence, by the end of the 18th century, deforestation was also encouraged by legislative measures, the residents having the right to “clean up” (“*curături*” in Romanian) to cultivate the land with the commitment to give the owner 1/10 of the harvest [33]. In addition, during the post-war period, the development of an intensive agriculture on increasingly large surfaces constituted by merging farming plots according to economic criteria [41] continued the massive impact on forest areas. Currently, the total agricultural area (arable land, pastures and hayfields, vineyards and orchards) still covers large shares (2,809,057 ha, which is over 80%). Concurrently, the dynamics of the rural-urban relations in the southern Romania have changed significantly in the last century in favor of the urban structures exerting a complex pressure on the rural space [42] which also includes valuable forest covered areas. Consequently, urbanization, industrialization, and, more recently, suburbanization processes [22] have enabled the emergence of some of the largest and most compact areas in Romania characterized by intense urban growth (the total built-up areas comprises 205,573 ha). Through time, agriculture, urbanization and suburbanization processes had led to significant spatial transformations, mainly at the expense of agricultural or forest-covered areas. As a result, according to the Corine Land Cover database (2012), in the study area, the forests spread over nearly 234,176 ha (Figure 4).

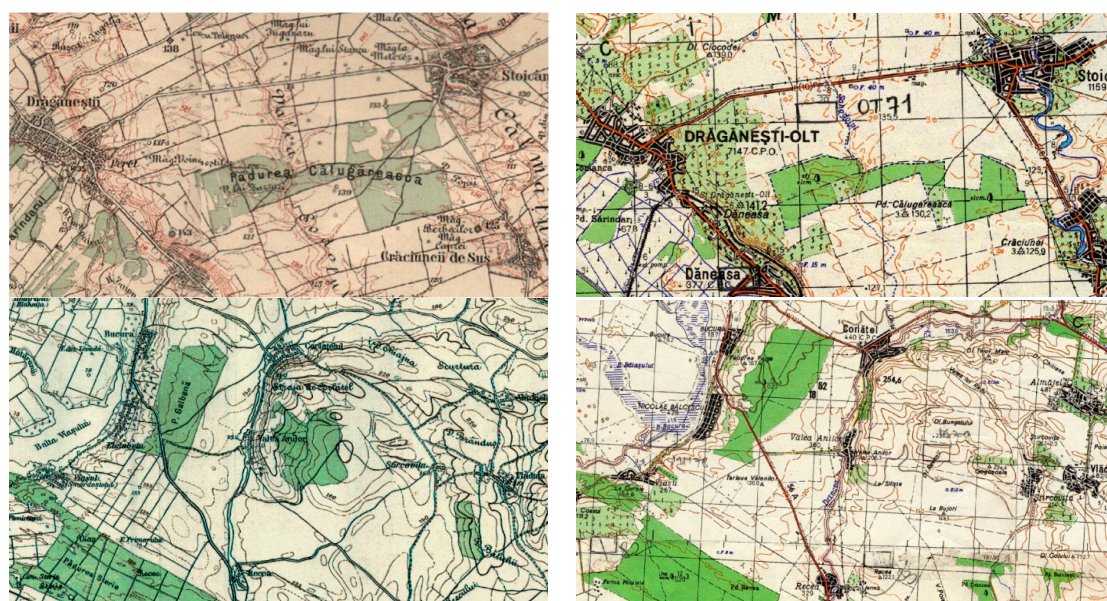
During the 19th and the 20th centuries, the main land reforms which have affected the Romanian land fund (1864, 1918–1921, 1945 and 1991) had significantly influenced land policies and land-use dynamics, which, in time was resumed to the enlargement of agricultural land and built-up areas to the prejudice of forestlands and grasslands [15]. Before 1948, 28% of forests were state owned, while during

the communism (1948–1989), almost entirely they come into the possession of state. After the fall of communism (1989), the restitution process, which brought back to the former owners nearly 35% of forests during the first two phases (1991 and 2000) and another 30% during the third (2005) [43], resulted in significant forest disturbances, mainly triggered by illegal logging and over-harvesting [6,10,14,15].



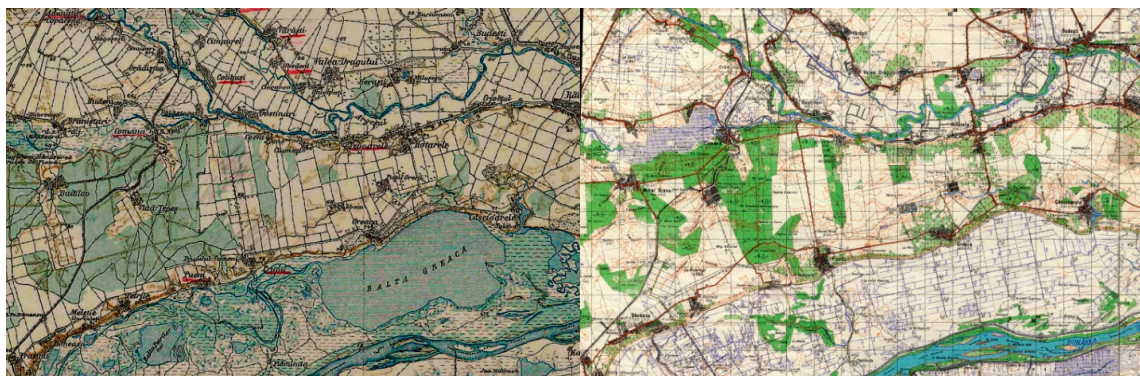
**Figure 4.** Land use/land cover in southern part of Romania (Corine Land Cover, 2012).

Thus, because of the diverse historical and socio-economic changes that took place over the past centuries, the human-related impacts (e.g., intensive/extensive agriculture, urbanization, industrialization) which have been affected Southern Romania has disturbed the natural ecosystems. Forest ecosystems, in particular, were the most affected, in many situations being replaced by secondary meadow associations (natural pastures and hay-fields). In the plain areas the largest share of oak forests, steppe and sylvo-steppe vegetation have been replaced by croplands [15,33]. As a result, some vegetation types reduced in size or almost disappeared, while others changed their floristic structure and composition [31]. For example, in the south-western part of the study-area (Oltenia Plain), until 1900, the old forests between Craiova, Caracal and Olteț which existed on the Specht (1790) and the Russian (1835) maps totally disappeared. Also, some other forest areas have reduced their surface or have disappeared during 20th centuries (e.g., Călugăreasca and Valea Anilor Forests) (Figure 5).



**Figure 5.** Comparative interpretation of historical forest withdrawal (1912–1990) in south-western part of Romanian Plain: Călugăreasca Forest and Valea Anilor Forest.

In the proximity of Bucharest, the capital-city, valuable forest ecosystems, remnants of the primeval forests, known as Vlășia Forests, have been significantly transformed by human intervention over the last hundred years. For example, Comana Forest covered 8000 ha in 1872 as compared to 5800 ha it covers today (a shrink of 27.5%) and Ciornuleasa Forest covered 4500 ha in 1872 as opposed to 1100 ha today (a 75.6% decrease) [22] (Figure 6).



**Figure 6.** Comparative interpretation of historical forest withdrawal (1912–1990) in Comana Forest.

In 1969, a political decision was taken to turn most of the Romanian Plain and Dobrogea Plateau into productive arable areas, leading to the deforestation of thousands of hectares of forests [33]. The environmental and ecological effects of this extended action were immediate and long-lasting, as they involved land degradation (the reactivation of sand dunes, soil erosion), forest fragmentation, biodiversity loss, habitats fragmentation, loss, and damage of valuable ecosystem services etc.

Moreover, the study area is currently affected by dryness and drought phenomena enhanced by the synergic interaction between climate change and land degradation triggered by deprived land management and land use/cover changes. Thus, the drop in the amount of precipitation and the rise of average annual temperatures have triggered significant changes in the quality and distribution of forest ecosystems [25,26]. The sylvo-steppe is more likely to be affected due to its increased sensitivity to climate change related effects [31,33]. However, there are some forest patches that have succeeded in maintaining their initial characteristics, and this recommended them for listing as protected natural areas after 1954. This category includes nature reserves of importance for their flora, fauna and/or forests, Natura 2000 sites (Special Areas of Conservation—SCI and—Special Protection Areas—SPA) and one Natural Park—Comana (Giurgiu County) falling into the IUCN category V (protected landscape/seascape).

The protected forest areas in the study area fall into the following biogeographical units: steppe (Hagieni, Constanța County), sylvo-steppe (Dumbrăveni—Constanța County, Ciornuleasa—Călărăși County, Troian—Teleorman County, Braniștea Catârilor and Călugăreasca—Olt County) and deciduous forests represented by the subzone of submesophyllic-thermophilic oak forests (e.g., Seaca-Optășani, Topana—Olt County, Plenița, Vela—Dolj County, Comana) and Submediterranean forests (Canaraua Feti and Esechioi—Constanța County). To these, the floodplain forests unfolded along the Danube, Olt and Jiu floodplains are added. Up to now, the biogeographical value of protecting forest ecosystems in southern Romania (Figure 7) has not been sufficiently addressed in the scientific literature, thus an insight on the significance, evolution, and conservation status of these valuable ecosystems in an area so exposed to human pressure is essential.



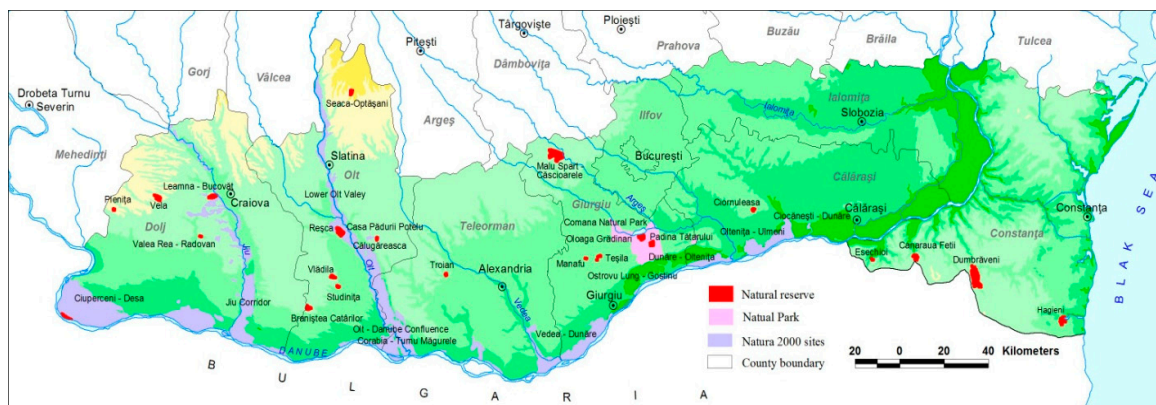


Figure 7. Natural protected areas in Southern Romania (processed after [44], updated).

#### 4.2. The Phytogeographical Importance of Forest Ecosystems

Due to their valuable phytogeographical structure, significant stands of southern species found in the biogeographical space located in southern Romania are protected by the law. Some belong to the ecosystem of “Moesian xerophile oak forests” (e.g., the stands of Vlädila and Studinița–Olt County, Manafu–Giurgiu County, Cälugăreasca and Braniștea Catârilor), others to the “Balkan forests of *Quercus cerris* and *Quercus pubescens*” (e.g., Canaraua Fetii and Esechioi) and others to the “Danubian-Balkan forests of *Quercus cerris*” (Comana Forest) or the “Danubian forests of *Quercus cerris* and *Quercus frainetto*” (Plenița Forest).

Mixtures of *Quercus pedunculiflora* and *Quercus pubescens* are preserved in the woodlands of Vlädila and Braniștea Catârilor or Hagieni (Constanța County). Other stands consist of *Quercus pedunculiflora*, *Quercus pubescens* and *Quercus cerris* (Dumbrăveni, Canaraua Fetii, Cälugăreasca and Teșila), *Quercus pedunculiflora*, *Quercus pubescens* and *Quercus cerris* (Esechioi) or *Quercus cerris*, *Quercus frainetto* and *Quercus pedunculiflora* (Manafu).

Also under protection are the mixed associations of *Quercus frainetto* and *Quercus cerris* in Topana Forest found at the highest altitude of its geographical area in protected forest areas, namely Vela (Dolj County), Saru (Olt County) and Troian (Teleorman County).

Other reserves have preserved valuable pure stands of some species, e.g., the purest *Quercus frainetto* stand in Romania (2146 ha, 240–330 m alt.) in Seaca-Optășani Forest, part of the “Danubian *Quercus frainetto* forest” ecosystem, which is the best-preserved site of this species [43]. A protected pure stand of *Quercus pubescens* lays in Studinița Forest, as it is unique in Olt County.

The only virgin stands maintained in the lowlands of Romania and protected over 1263 ha is found amid Malu Spart-Căscioarele Forest (Giurgiu County). “This is the most representative forest in the whole area of the *Quercus robur* species” ([38], p. 125). Some specimens are 100 years old, up to 36 m tall and maximum of 94 cm in diameter.

Stands going back one or several hundreds of years are also being protected. Most of them are in Studinița Forest, a few oaks in Comana Forest (Figure 8a) and “Casa Pădurii Potelu” Reserve (Olt County), which shelters three 400-year-old monumental trees, the biggest being 6 m girth at 0.6 m from the ground. They are “remnants” of the old floodplain woods. In Braniștea Catârilor Forest, there is a several-centuries old *Quercus pedunculiflora* tree, 5 m girth at 0.6 m from the ground. In the Seaca-Optășani Forest protected area (ca. 140 ha) (Figure 8b), *Quercus frainetto* stands are of 150 years old, while in Ciornuleasa Forest Natural Reserve *Quercus robur* and *Quercus pedunculiflora* stands are over 120 years old (Figure 8c).

Protective actions had in view the special southern xerothermic associations, as well. It is the case of *Carpinus orientalis* (in Dumbrăveni, Canaraua Fetii, Esechioi, Hagieni and Ciornuleasa Forests), *Jasminum fruticans* (in Dumbrăveni, Esechioi and Hagieni Forests), *Fraxinus ornus* (in Canaraua Fetii, Esechioi, Hagieni, Comana and Ciornuleasa Forests), *Prunus mahaleb* (in Canaraua Fetii, Esechioi,

Hagieni and Ciornuleasa Forests), *Cotinus coggygria* (in Esechioi, Hagieni and Ciornuleasa Forests), *Paliurus spina-christi* (Esechioi, Hagieni and Manafu forests), *Caragana frutex* and *Syringa vulgaris* (in Esechioi Forest). They form a characteristic Balkan-type association named “meshelik” (of Turkish origin) in Dobrogea Region.



**Figure 8.** *Quercus* sp. stands in Comana Natural Park, Giurgiu County (a), Seaca-Optășani Natural Reserve, Olt County (b), and Ciornuleasa Natural Reserve, Călărași County (c), (photo: Ines Grigorescu and Sorin Geacu).

In the study area, also protected are some rare tree species, such as *Fraxinus pallisse* (in Ciornuleasa and Comana forests), *F. cariariifolia* (in Comana Forest) and *F. angustifolia* (in Reșca Forest). Leamna-Bucovăț Forest (in Dolj County) shelters *Fagus sylvatica* [45]. Most of these species were logged in the early 1960s, only a few individuals have remained in Seaca-Optășani Forest [46]. Also, *Quercus dalechampii* grows at top altitudes in Seaca-Optășani and Topana Forests.

Rare species of grasses are found in other nature reserves. For example, Canaraua Fetii Forest hosts rare species in Romania: *Crucianella angustifolia*, *Ornithogalum oreoides*, *Cytisus agnipilus*, *Linum tauricum*, *Centaurea varnensis*, *Astragalus haarbachii*, ssp. *macedonicus*, *Dianthus giganteus*, *Thymus zygioides* and *Parietaria serbica* [39]; Comana Forest shelters *Alyssum rostratum* and *Asparagus verticillatus*; in Desa Forest (Dolj County), on the edge of acacia stands there is *Alkanna tinctoria*, a rare species in Oltenia region [47]; in the Hagieni Forest, 10.8% of the vegetal taxa are rarities [28].

The legal status of some protected areas had in view the protection of valuable biogeographical elements, too. It is mainly the case of *Paeonia peregrina*, var. *romanica*, a Balkan element linked to the *Quercus cerris* species (Comana Forest) and seen also in the forests of Hagieni, Canaraua Fetii, Manafu and Plenița. The shrubs area (ca. 18 ha) in Plenița extends in the north-east of the forest, at 209–217 m alt. [48]. There is also a wealth of this species in the *Quercus pubescens* sector of Călugăreasca Forest.

Noteworthy, in Comana Forest, one can find all *Fraxinus* species (*F. ornus*, *F. excelsior*, *F. cariariifolia*, *F. pallisae* and *F. angustifolia*) [29].

The Red List of Plants in Romania records *Ruscus aculeatus*, an Atlantic-Mediterranean species (in Comana Forest) (Figure 9). Other sites are Leamna-Bucovăț [39], Canaraua Fetii and Esechioi forests.

Outstanding are also the forest reserves conserving relict and endemic species. Thus, Esechioi and Canaraua Fetii shelter a very rare xerothermic Iranian-Turanic element, namely *Caragana frutex* [49]. Among endemisms there are *Campanula rotundifolia* ssp. *romanica* [28], *Erythronium dens-canis* (Plenița Forest) and *Dianthus trifasciculatus*, ssp. *deserti* (Comana Forest) [50]. Here are some particularly important associated phytogeographical elements: Pontic-Mediterranean: *Crocus reticulatus* (Canaraua Fetii, Reșca and Călugăreasca forests), *Convolvulus cantabrica* (Canaraua Fetii) and *Centaurea iberica* (Comana); Pontic-Sarmatian: *Poa versicolor* (Dumbrăveni); Pontic-Pannonian: *Fraxinus angustifolia* (Reșca and Comana); Pontic-Caucasian: *Fraxinus cariariifolia* (Comana) and *Tulipa biebersteiniana* (Reșca);

Pontic-Balkan: *Nectaroscordum siculum*, ssp. *bulgaricum* (Comana, the species is on the Red List of Plants in Romania), *Symphytum tauricum* (Ciornuleasa), *Fraxinus pallisae* (Ciornuleasa and Comana), *Scabiosa micrantha* (Hagieni) and *Linum tauricum* (Canaraua Fetii); Balkan-Anatolian: *Iris sintenisii* (Canaraua Fetii), *Crocus chrysanthus* (Hagieni and Dumbrăveni), *Comandra elegans* (Comana) and *Stachys obliqua* (Hagieni); Balkan-Caucasian: *Allium atrovioleaceum* and *Fritillaria tenella* (Comana), *Salvia ringens* (Hagieni); Balkan-Anatolian-Caucasian: *Arum orientale* and *Viola jordanii* (Plenița); Pontic-Pannonian-Balkan: *Ajuga laxmanni* (Braniștea Catârilor); Alpine-Balkan-Tauric: *Mercurialis ovata* (Reșca); Illyric-South Italian: *Quercus dalechampii* (Seaca and Topana); Carpathian-Balkan-Anatolian: *Quercus polycarpa* (Comana).



**Figure 9.** *Ruscus aculeatus* bush in Comana Natural Park (photo: Ines Grigorescu).

The following species are of Balkan origin: *Knautia macedonica* (Comana), *Crocus moesiacus* (Comana, Leamna-Bucovăț, Radovan- Dolj County and Canaraua Fetii); *Dianthus trifasciculatus*, ssp. *deserti* (Comana), *Ranunculus constantinopolitanus* (Comana and Reșca, registered in the Red List of Plants in Romania), *Galanthus graecus* (Hagieni and Dumbrăveni), *Symphytum ottomanum* (Seaca-Optășani), *Genista trifoliata* (Hagieni), *Cytisus agnipilus*, *Centaurea varnensis*, *Dianthus giganteus*, *Thymus zygoides* and *Parietaria serbica* all in Canaraua Fetii forest and *Paeonia peregrina*, var. *romanica*.

There are many Submediterranean-Mediterranean species: *Asphodeline lutea* (Hagieni and Esehioi), *Astragalus spruneri*, *Vicia amphicarpa* and *Quercus virgiliana* (Hagieni), *Digitalis ferruginea* (Leamna-Bucovăț and Bistreț-Dolj County), *Asparagus verticillatus* and *Scilla autumnalis* (Comana), *Astragalus haarbachii* (Canaraua Fetii and Esehioi), *Chrysopogon gryllus* (Ciornuleasa), *Crataegus pentagyna* and *Rosa gallica* (Reșca), *Sternbergia colchiciflora* and *Ziziphora capitata* (Radovan), *Crucianella angustifolia* and *Astragalus haarbachii*, ssp. *macedonicus* (Canaraua Fetii), *Alkanna tinctoria* (Desa), *Quercus cerris*, *Quercus frainetto*, *Quercus pubescens*, *Jasminum fruticans*, *Paliurus spina-christi*, *Prunus mahaleb*, *Cotinus coggygria*, *Fraxinus ornus* and *Carpinus orientalis*.

Also important are the Pontic elements—*Alyssum rostratum* (Comana), *Asparagus verticillatus* (Comana), *Urtica kiovensis* (Comana, found on the Red List of Plants in Romania), *Acer tataricum* (Comana), *Potentilla bornmuelleri* (Hagieni), *Ornithogalum oreoides* (Canaraua Fetii) and *Quercus pedunculiflora*.

There are protected areas that have a high proportion of Mediterranean, Balkan, and Pontic elements in the inventory of vegetal taxa: 17.6% Submediterranean and Balkan and 10.6% Pontic and Pontic-Mediterranean in Esehioi and Canaraua Fetii forests [51]; 12.2% Submediterranean, 17%

Pontic and Pontic-Mediterranean, 5.9% Balkan and Balkan-Mediterranean in Comana Forest [50]; 16% Mediterranean, 2% Balkan-Mediterranean and 2% Pontic-Mediterranean in Plenița Forest [52].

Hagieni Forest is the only site in Romania hosting species such as *Potentilla bornmuelleri*, *Genista trifoliata*, *Vicia amphicarpa*, *Scabiosa micrantha*, *Stachys oblique* and *Salvia ringens* [28], while *Mercurialis ovata* grows only in the Oltenia region (in Reșca Forest) [53].

Some protected areas shelter plants characteristic to the higher-altitude vegetation belts. It is the case of Comana Forest with *Anemone nemorosa*, *Convallaria majalis*, *Salvia glutinosa*, *Angelica sylvestris* and *Quercus polycarpa* specific to the *Quercus petraea* belt [29], and *Asperula odorata* and *Mercurialis perennis* peculiar in beech forests alone. *Quercus petraea* and *Fagus sylvatica* woods lie 100 km north of Comana Forest.

In the Ciurumela-Tunari Forest (Dolj County), one may still find the first *Robinia pseudacacia* stands used to stabilize the sand dunes one hundred years ago.

#### 4.3. The Zoogeographical Importance of Forest Ecosystems

Forest ecosystems also provide shelter for some populations living at the limit of their geographical area in Europe, thus requiring effective preservation measures. Thus, Esechioi Forests represents the northern limit of two butterfly species *Zerynthia cerisyi ferdinandi* and *Dysanctes fumula pontica* and the north-western bounds of *Perisomena caecigena* (Lepidoptera). Canaraua Fetii and Ciuperceni forests are the northern extremity of *Pelobates syriacus balcanicus* (Amphibia) species. Also, *Hedychridium jucundum* (Hymenoptera) has its northern limit in Canaraua Fetii [54], *Bucephala bucephala* (Orthoptera) in Hagieni Forest and *Limax macedonicus* (Gastropoda) in Canaraua Fetii Forest.

Other reserves protect species that have their world boundary in this region. For example, Esechioi Forest represents the western limit of *Phytoecia praetextata* (Coleoptera), a species existing only in Bulgaria, the Crimea Peninsula, the Caucasus Mts., Armenia, and Syria [40]; similarly, the northern boundary of *Purpuricenus oblongomaculatus* (Coleoptera), a species known only in Algeria, Spain, Greece, Turkey, and Syria. The northern limit of *Nemesia pannonica coheni* (Araneae) is in Hagieni Forest, and the western boundary of *Onthophagus parmatius* (Scarabaeidae), still found only in Armenia today is in Canaraua Fetii. Dumbrăveni Forest registers a critically endangered species, *Vipera ammodytes montandoni* (Reptilia).

In terms of biogeographical origin of species, worth mentioning are some Mediterranean zoo-elements *Carpocoris mediteraneus* (Heteroptera) in Dumbrăveni Forest, *Argiope lobata* and *Ersus niger* (Araneae) in Canaraua Fetii, *Euchloe ansonia* (Lepidoptera) in Dumbrăveni [30], *Zerynthia cerisyi ferdinandi* (Lepidoptera), *Zebrina varnensis* (Gastropoda) and *Hedychridium jucundum* (Hymenoptera) in Canaraua Fetii. In Hagieni Forest, outstanding Mediterranean species (18.6% of the forest's Araneae fauna) [55] are the spiders *Nemesia pannonica coheni* and *Araneus subfuscus* in Hagieni Forest.

A Pontic element is the gastropod *Bulgarica varnensis* (Dumbrăveni Forest). In addition, Balkan elements are the frog *Pelobates syriacus balcanicus*, the snail *Limax macedonicus* (Canaraua Fetii), the bird *Dendrocopos syriacus balcanicus*, the coleopter *Carabus (Procerus) gigas*, the butterfly *Zerynthia cerisyi ferdinandi* (Esechioi) and the orthopter *Bucephala bucephala*, an Anatolian-Balkan element (Hagieni Forest).

Other reserves shelter the last individuals of the following species: the mammal *Martes foina* in Canaraua Fetii and the bird *Neophron percnopterus* in Hagieni Forest [56].

In the process of bird migration, protected areas provide places for resting and feeding, or even mating for certain species (*Scolopax rusticola*, *Columba Oenas*, *Streptopelia turtur*, *Columba palumbus* and for predatory birds). It is the case of Natura 2000 Sites located at the confluence of Olt and Jiu rivers with the Danube, the Jiu Corridor, Zăval and Ciuperceni Forests (Dolj County), the Lower Olt Valley (Olt County), or the islets along the Danube River or in the Danube Floodplain: Șoimu, Haralambie and Ciocănești, in (Călărași County), Gâsca and Mare (Teleorman County).

Some of the protected forest areas act as “entrance gates” to Romania for new species of fauna, e.g., Hagieni Forest for the bird *Passer hispaniolensis*, Canaraua Fetii and Dumbrăveni for birds *Apus melba* and *Lanius senator*, as well as for the butterfly *Apatele orietalis gelvani*.

It is interesting to note that some rare and very rare species have continued to exist in different forest areas such as: Canaraua Fetii Forest-*Anthaxia plicata* (Coleoptera), *Helicella candicans dobrudschae*, *Helix pomatia dobrudschae* and *Campylaea trizona dobrudschae* (Gastropoda), *Onthophagus kindermanni* and *Onitis damoetas* (Scarabeidae); Esehioi Forest-*Purpuricenus oblongomaculatus* and *Brachynus bayardi* (Coleoptera); Hagieni Forest-*Proatypus muralis* and *Coelates longispina* (Araneae); Seaca, Topana and Comana forests-the mammal *Felis silvestris*. Therewith, Hagieni Forest was the first site in Europe in which the *Cheilosia rogersi* species (Diptera) was identified [57]. Moreover, the only site of *Berotha fulva* (Neuroptera) is Canaraua Fetii [58].

Of particularly importance are some of the species listed in the Red List of Vertebrates recorded in Romania: *Pelobates syriacus balcanicus* (Amphibia), *Testudo graeca* (Reptilia)–endangered and *Vipera ammodytes montandoni* (Reptilia)–critically endangered (Canaraua Fetii, Esehioi and Hagieni), *Neophron percnopterus* (Aves)–critically endangered (Canaraua Fetii and Hagieni), *Falco cherrug* (Aves)–critically endangered (Comana), *Jynx torquilla* (Aves)–endangered (Comana), *Corvus corax* (Aves)–endangered (Branîştea Catârilor, Reşca, Canaraua Fetii and Hagieni forests).

Among the few endemic species still in place are: *Lacerta trilineata dobrogica* (Reptilia) in Canaraua Fetii, Esehioi and Dumbrăveni [59], *Nemesia pannonica coheni* (Aranea) and *Goniodoma nemesi* (Lepidoptera) in Hagieni, and *Deroceras geticus*, *Daude hardia rufa getica* (Gastropoda) and *Paragus bradescui* (Hymenoptera) in Comana Forest.

Also important are some of the relict specimens: *Limax grossui* (Gastropoda) in Esehioi and Hagieni, *Amphipyra styx* (Lepidoptera) in Canaraua Fetii and *Diachrysis metelkana* (Lepidoptera) in Hagieni Forest.

## 5. Conclusions

The first half of the 19th century brought in an increased human pressure which has altered and fragmented forest ecosystems in the southern part of Romania. If at the beginning, wood was mainly used as construction material or heating source needed for settlement expansion or family needs, soon after, industrialization, urbanization and sub-urbanization processes become the main triggers of deforestation, posing increasingly higher pressures to forest ecosystems, thus jeopardizing the valuable biogeographical elements they engulf. In terms of the present-day biogeographical regions in Europe, the protected forest areas which fall into the analyzed area belong to the Pontic, Steppe and Continental Biogeographical Regions. Currently, the existing forests are “remnants” of the compact forests which once stretched on extended territories hosting significant phytogeographical and zoogeographical features. The six counties studied herein include protected forests of high biogeographical importance over small areas, recording the lowest national forest area (between 4% and 11% of their territory). The biogeographical significance of present-day forests is related to their role in preserving plant and animal species important for the continuity and resilience of ecological systems. They represent valuable protection sites for southern species stands; for certain xerothermic species; for some “pure” or “virgin” trees; for some rare (ligneous or herbaceous), endemic, relict and unique species recorded in the Red Lists [60] and Red Books [61]; for species living on the bounds of their spreading area; for connective phytogeographical elements and for a few centuries-old stands. The preserved forests also underwent changes of the flora and fauna over time, but some of them retained much of their original character, thus after 1954 some of them were declared natural areas protected under different categories. When referring to Canaraua Fetii Forest (southern Dobrogea Plateau), researchers Săvulescu and Popescu-Gorj wrote that “from an entomological viewpoint, this is a patch of the southern lands around the Mediterranean that had strayed in our parts” [40]. Protected forest lands date back to 1954, but three of the species found there had been protected long before, basically since 1939 (*Crocus moesiacus*, *Ruscus aculeatus* and *Paeonia peregrina*, var. *romanica*) and 1940 (*Corvus corax*).

Some of the key findings of the current study sum up to the following:

- Over the last hundred years, in the proximity of large cities (e.g., Bucharest, Craiova), valuable forest ecosystems which were remnants of the primeval forests have been significantly transformed by human intervention under urban development processes and agricultural expansion;
- In particular forest stands, significant spatial shrinkage of the woodland has been registered throughout time. e.g., Comana Forest from 8000 ha in 1872 as compared to 5800 ha; Ciornuleasa Forest from 4500 ha in 1872 to 1100 ha today;
- The altered ecological conditions (e.g., soil degradation, erosion, the extension of sand dunes) from the intensively modified forest ecosystems, especially in the proximity of large cities or extensive farms, hardly preserved the ecological conditions for the persistence of valuable plant species of biogeographical importance until now;
- The degradation of forest ecosystems (habitat for many animal species) generally put additional pressure on threatened and endangered species, or even brought in the loss of some animal species of biogeographical importance;
- The potential of several forest patches to preserve their initial characteristics recommended them as witnesses of the primary ecosystems, thus being listed as protected natural areas as of 1954;
- Valuable stands of southern species found in the biogeographical space located in southern Romania belong to the ecosystem of “Moesian xerophile oak forests”, “Balkan forests of *Quercus cerris* and *Quercus pubescens*”, “Danubian-Balkan forests of *Quercus cerris*” and “Danubian forests of *Quercus cerris* and *Quercus frainetto*”;
- The study area hosts the only virgin stands of *Quercus robur* in Romania, as well as some old-growth forest stands: *Quercus frainetto* (150 years old) and *Quercus robur* and *Quercus pedunculiflora* (over 120 years old);
- Southern Romania houses rare tree and grass species and protects valuable biogeographical elements (e.g., *Paeonia peregrina*, var. *romanica*, *Ruscus aculeatus*), relict and endemic species (e.g., *Caragana frutex*, *Campanula rotundifolia* ssp. *Romanica*, *Erythronium dens-canis*);
- Some protected areas shelter plants characteristic to the higher-altitude vegetation belts: *Anemone nemorosa*, *Convallaria majalis*, *Angelica sylvestris*, *Asperula odorata* etc.
- In Southern Romania there is the limit of some species of fauna in Europe (e.g., *Zerynthia cerisyi ferdinandi*, *Dysanctes famula pontica*, *Pelobates syriacus balcanicus*, *Limax macedonicus*) or worldwide (*Phytoecia praetextata*, *Nemesia pannonica coheni*, *Vipera ammodytes montandoni*);
- Some reserves shelter the last individuals of some fauna species: *Martes foina*, *Neophron percnopterus*, as well as species listed in the Red List of Vertebrates recorded in Romania (e.g., *Pelobates syriacus balcanicus*, *Testudo graeca*, *Vipera ammodytes montandoni*, *Falco cherrug*, *Jynx torquilla*), endemic (e.g., *Lacerta trilineata dobrogica*, *Nemesia pannonica coheni*, *Goniodoma nemesi*, *Deroceras geticus*, *Daudehardia rufa getica*) and relict (e.g., *Limax grossui*, *Amphipyra styx*, *Diachrysis metelkana*) species;
- All the above demonstrate the biogeographical significance of some old, rare, or pristine species which have survived throughout time in certain forest stands for the protection and maintenance of valuable ecosystems in an area under significant human transformation.

However, the long-term and intense human impact this area was subject to, have extensively affected the integrity and structure of the valuable forest ecosystems. The authors used selected indicative taxa (*Quercus* species) and witness species considered important for southern Romania to re-establish past forest stands and justify their biogeographical significance for the present-day ecosystems. Currently, these forest ecosystems persist as “patches” from the old forest areas which existed in the past centuries, both in the plain and in the Danube floodplain areas. The scientific importance of the current results consists in supporting further reconstructing of the primeval natural landscapes through the evaluation of indicative taxa and witness species, but also in identifying areas with different needs in terms of applying biodiversity conservation and protection measures. The current study contributes to the enrichment of biogeographical knowledge about the valuable

plant and animal species in Romanian forest ecosystems. Under the continuous human impact and landscape transformations, most of them fall under decline or extinction threatening the integrity and functioning of the ecosystems they are part of. On that account, improving the knowledge of the occurrence and dynamics of species of biogeographical significance and being aware of their potential loss is particularly important for the sustainable management of forest ecosystems through adopting conservation strategies, management plans and effective measures for their preservation. All the above can be easily achieved by way of declaring valuable forest areas as protected sites and applying area-based conservation measures. Overall, this helps meeting the one of foremost objectives of the Goals for European Forests and the European 2020 Targets for Forests, i.e., sustainable forest management (SFM). The occurrence of the selected indicative and witness species in various protected forest areas in southern Romania stand for the continuity and resilience of valuable ecological systems under the increased human impact and related environmental changes.

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