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Original Article

Floristic Diversity and Conservation Status of Strictly Endemic Taxa of Talassemtane National Park in Morocco

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What is already known on this topic?

- Currently, the exceptional plant diversity of Talassemtane National Park (TNP) is under serious threat, a situation worsened by the limited data available on its endemic species, which heightens the potential for biodiversity loss.

What this study adds on this topic?

- A total of 100 strictly endemic plant species were identified in TNP and surrounding areas, most of which have not been assessed by the IUCN and are primarily found above 1400 meters in Moroccan fir and holm oak forests. Cluster analysis revealed three ecological groups, with one broadly tolerant group and two others showing strong dependence on specific environmental conditions.

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ABSTRACT

Talassemtane National Park (TNP), located in the Central-Western Rif of northwest Morocco, is a protected area renowned for its exceptional floristic diversity and a high level of endemism (24%). However, the unique richness of this flora faces significant threats, compounded by a lack of comprehensive data on its endemic species, increasing the risk of biodiversity loss. This study aims to enhance the understanding of the floristic diversity of strictly endemic taxa in the park and its surrounding areas, evaluating their presence and conservation status. The methodology used in this study involved field surveys and the mapping of distribution areas to identify and characterize the habitats of strict endemic taxa based on a set of ecological criteria. Spatial and cluster analysis was then applied to explore the relationships between these habitats. As a result, a list of 100 strictly endemic taxa in Talassemtane National Park and surrounding regions was compiled. Most of these taxa have not yet been assessed for their conservation status by the International Union for Conservation of Nature. The findings indicate that the majority of these taxa are found at higher elevations, above 1400 meters, particularly within the forests of Moroccan fir (*Abies marocana* Trabut) and holm oak (*Quercus rotundifolia* Lam.). The cluster analysis of ecological variables and the endemic taxa revealed three distinct groups of taxa with varying ecological preferences. The first group consists of 67 taxa that are largely unaffected by ecological variables, while the second and third groups, containing 33 and 38 taxa respectively, are more closely associated with specific environmental factors, indicating their reliance on particular habitat conditions.

Keywords: Conservation, diversity, Morocco, strict endemic, Talassemtane

Introduction

The issue of biological diversity has been a concern for ecologists long before the term "biodiversity" was introduced (Eric, 2015; Díaz & Malhi, 2022). However, due to the ongoing loss of biodiversity and the urgent need for its conservation, it has become a critical global issue. Over recent centuries, human activities have significantly altered ecosystems and biodiversity worldwide. Yet, the long-term trends of biodiversity and how much they have been affected by human actions remain inadequately understood (Gordon et al., 2024; Newbold et al., 2015).

Protected areas (PAs) have existed since the late 19th century, and after the Convention on Biological Diversity was signed by most countries in 1992, a global commitment was made to implement broad, sustainable conservation efforts for biodiversity. As a result, the extent of PAs has significantly expanded, and the conservation status of various plant and animal species is regularly assessed by the International Union for Conservation of Nature (IUCN). Protected areas have become essential for conserving nature, and when properly managed, they can substantially reduce human impacts and threats to biodiversity (Ceballos et al., 2015; Pulido-Chadid et al., 2023). However, many PAs fall short of effectively preserving biodiversity, with human pressures inside them sometimes rivaling or even exceeding those in un-PAs (Laurance et al., 37; Laaribya et al., 2021; Leclère et al., 2020).

Talassemtane National Park, located in Morocco, is one such PA and is part of the Intercontinental Biosphere Reserve of the Mediterranean, designated by UNESCO on October 25, 2006. Situated in the Western Rif mountains of northern Morocco, the park is a remnant of ancient forests (Baumer, 1977) and is renowned for its remarkable floristic diversity, including its distinctive woody formations such as the Moroccan fir, as well

as a large number of endemic species, which were key reasons for its establishment (Benabid & Fennane, 1994).

Although numerous studies have been conducted on the park's biogeographical significance and biodiversity (Emberger & Maire, 1941; Baumer, 1977; Benabid, 1984; 10; 11; Boukil, 1998; Minerva et al., 2003; Carine et al., 2006; Chambouleyron, 2012; Alaoui et al., 2021), the status and conservation of strict endemic species in the park and surrounding areas remain poorly documented. Most of these species have not been assessed or listed by the IUCN, and some are thought to be vulnerable, endangered, or even critically endangered according to Fennane (22). Given this situation, it is crucial to focus on the endemic, rare, and threatened flora in Morocco, as these species are vital for biodiversity conservation. Additionally, having comprehensive information about this heritage is necessary for taking informed actions to develop protection and conservation programs.

This work was, therefore, initiated to enhance our understanding of the spatial distribution of strict endemic species in the park and its vicinity, to characterize their habitats, and to assess their conservation status.

Methods

Study Area

Talassemtane National Park (TNP) is a PA that is part of the Intercontinental Biosphere Reserve of the Mediterranean. It is primarily located on the limestone ridge of the Central-Western Rif, at the extreme northwest of Morocco (Figure 1).

The Park spans 58,000 hectares, of which 42,267 hectares (73%) are forests (Alaoui et al., 2021). These forests contain flora that has developed on highly varied substrates and under different bioclimatic conditions (Baumer, 1977; Boukil, 1998; Benabid, 2000). According to the global bioclimatic classification system developed by Rivas-Martínez & Rivas-Sáenz (50), the study area falls within the Mediterranean macro-bioclimatic zone, known for its marked summer drought. However, its geographical location between the relatively rainy Atlantic coastline and the drier Mediterranean coast favors a climate moderation, characterized by reduced thermal variations and the abundance of fog, which compensates for summer rainfall and the temperature contrasts (Redouan et al., 2020). These geological and ecological characteristics, combined with the Park's location within a mountain range that includes both plains and highlands as well as rugged terrain, have made it an area of original biodiversity.

The park contains the only known populations of the Moroccan fir (*Abies marocana* Trabut), classified by the IUCN in the Red List of Threatened Species as endangered (Alaoui et al., 2011). Other species that define the forest formations in the park include the black pine (*Pinus nigra* subsp. *mauretanica* (Maire & Peyerimh.) Heywood), an Algero-Moroccan endemic with the last remaining populations in TNP, with Algeria holding only a few 100 individuals; the mountain maritime pine (*Pinus pinaster* subsp. *maghrebiana* Villar), a Moroccan endemic; the Atlas cedar (*Cedrus atlantica* (Endl.) Manetti ex Carrière), an Algero-Moroccan endemic; the kermes oak (*Quercus coccifera* L.) and the Portuguese oak (*Quercus faginea* Lam.), whose populations are very limited in Morocco; and the Barbary thuja (*Tetraclinis articulata* (Vahl) Mast.), with Moroccan populations representing nearly 90% of this Maghrebian endemic species (Achhal et al., 1980; Ghallab et al., 26).
The methodological approach adopted includes the following phases:

Data Collection: All research related to the floristic diversity of TNP was gathered to first compile a list of the present taxa. We then focused on the strictly endemic taxa in TNP and its surrounding areas, extracting their qualitative data (diversity, rarity, conservation status, etc.) and geographical indications.

Field Verification: Field visits were conducted to confirm or update the presence of taxa in the localities indicated in the literature. In the year 2023, we conducted three field trips based on seasonal variations: the

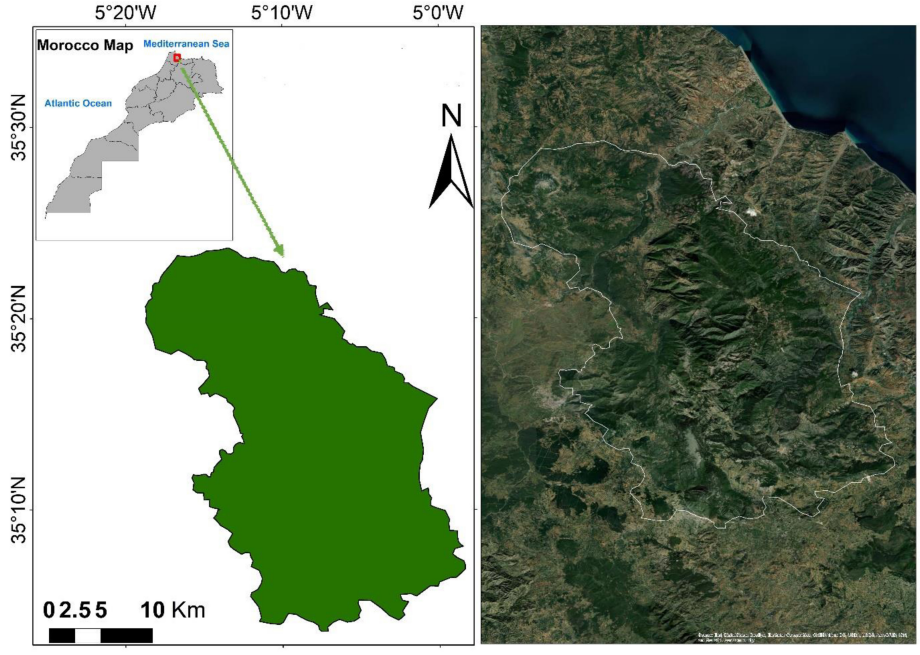

Figure 1.
Study Area.

first trip in early spring to identify early spring-flowering species, the second in late spring, and the third in early autumn.

Evaluation of Rarity and Conservation Status: The rarity and conservation status of endemic taxa in TNP and its surrounding areas were assessed by synthesizing the work established by Benabid (2008) and Fennane (2021). Information is also available at http://www.floramaroccana.fr/, http://www.florasilvestre.es/, and https://africanplantdatabase.ch

For determining the conservation status of each taxon, we also used the IUCN database (2024) and the IUCN Red List of Threatened Species. Additional information on many endemic Moroccan taxa that are lacking in the IUCN database is available in the publication by Fennane (22), where the author adopted a system similar to that of the IUCN (2012a) and 2012b) in terms of criteria and evaluation methods, as a suffix to the abbreviations of threatened categories.

Mapping and Clustering: Mapping was used to identify and characterize the habitats of strict endemic taxa based on a set of ecological criteria such as exposure, substrate type, the type of vegetation community in which each taxon is found, and vegetation belts corresponding to groups of plant communities with ecological affinity within the same altitude range (Ozenda, 1975). Spatial and cartographic analysis refers to the study and interpretation of geographical data and spatial relationships through maps and other visualization tools (ArcMap 10.8 software). The relationship between the habitats of the strict endemic taxa in the park and its surrounding areas was revealed by cluster analysis using hierarchical ascending classification. This method, also known as hierarchical agglomerative clustering, is widely used in data analysis and machine learning. Hierarchical ascending classification is a type of clustering algorithm that builds a hierarchy of clusters by iteratively merging or dividing them based on similarity or distance metrics (Sokal & Michener, 1958; Jain & Dubes, 1988; Kaufman & Rousseeuw, 1990).

Results

Floristic Diversity and Endemism

Talassemtane National Park harbors a great floristic diversity, with more than one 420 taxa reported in the consulted references (Maire, 1948; Ruiz de La Torre, 1956; Sauvage, 1968; Raynaud and Sauvage, 1975; Romo, 1993; Fennane & Ibn Tattou, 2005; Benabid, 2008; Dobignard, 2009; Fennane et al., 1999–2014; 1952–1986; Valdés et al., 2002; Romo & Soriano, 2005; Mateos & Valdés, 2006; 41; 42; Pyke et al., 2008; Alaoui et al., 2021). These taxa are distributed across 129 families, with 340 taxa (24%) being strictly endemic to TNP and its surrounding areas (100; 29.41%), Moroccan endemics (41; 12%), or endemics shared with neighboring countries. Specifically, 81 taxa (23.82%) are shared with the Iberian Peninsula, 51 taxa (15%) with Algeria, and 67 taxa (19.71%) are Ibero-Algerian-Moroccan endemics (Figure 2).

The strict endemic taxa of TNP primarily belong to the Eudicots (94 taxa). The monocots are represented by five taxa, while the gymnosperms are represented by only one taxon. These taxa belong to 66 genera spread across 34 families. The most represented families are Asteraceae (16 taxa), Caryophyllaceae (10 taxa), Lamiaceae (10 taxa), Brassicaceae (nine taxa), Caprifoliaceae (six taxa), Saxifragaceae and Fabaceae (five taxa each), Cistaceae, Fumariaceae, Poaceae, and Scrophulariaceae (three taxa each), and Convolvulaceae, Gentianaceae, Linaceae, and Plantaginaceae (two taxa each). The remaining families are each represented by only one taxon (Figure 3).

Rarity and Conservation Status

The 100 strict endemic taxa of TNP and its surrounding areas are classified into four rarity categories: 16% are extremely rare, 69% are very rare, 3% are rare, and 12% have an unknown rarity status (Figure 4). It is worth noting that some strict endemic taxa of TNP and its surroundings have not been observed since 1930, and the field visits we conducted allowed us to identify only 82 taxa (Table 1).

In TNP, 52% of the taxa are classified in the categories of critically endangered (CR/CRe), endangered (EN/ENe), and vulnerable (VU/VUe) taxa; they are therefore at risk of extinction. Twenty-two percent of the taxa fall into the near threatened (NT) category, meaning they are close to the threshold of being considered threatened and could potentially become so if specific conservation measures are not implemented. Taxa that have not yet been assessed (category NA) represent 10%, while taxa with a low risk of extinction (LC) and those for which there is insufficient data to assign a conservation status (DD) represent 13% and 3%, respectively, of the total strict endemics in TNP and its surroundings (Figure 5).

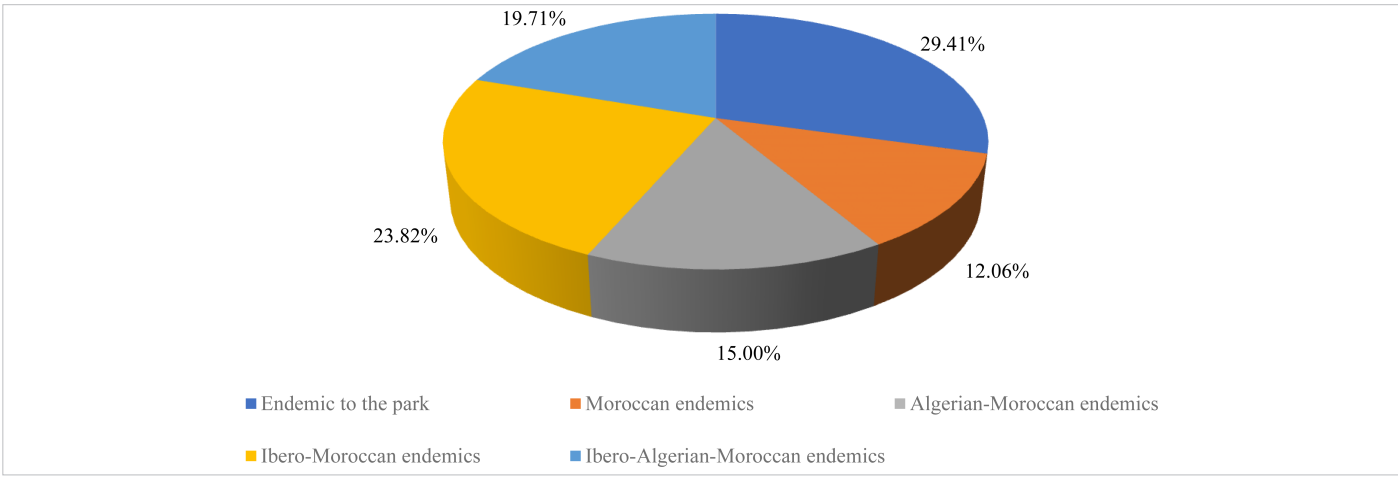

Figure 2.
Percentage of Taxa (Flora) by Origin of Endemism in the TNP.

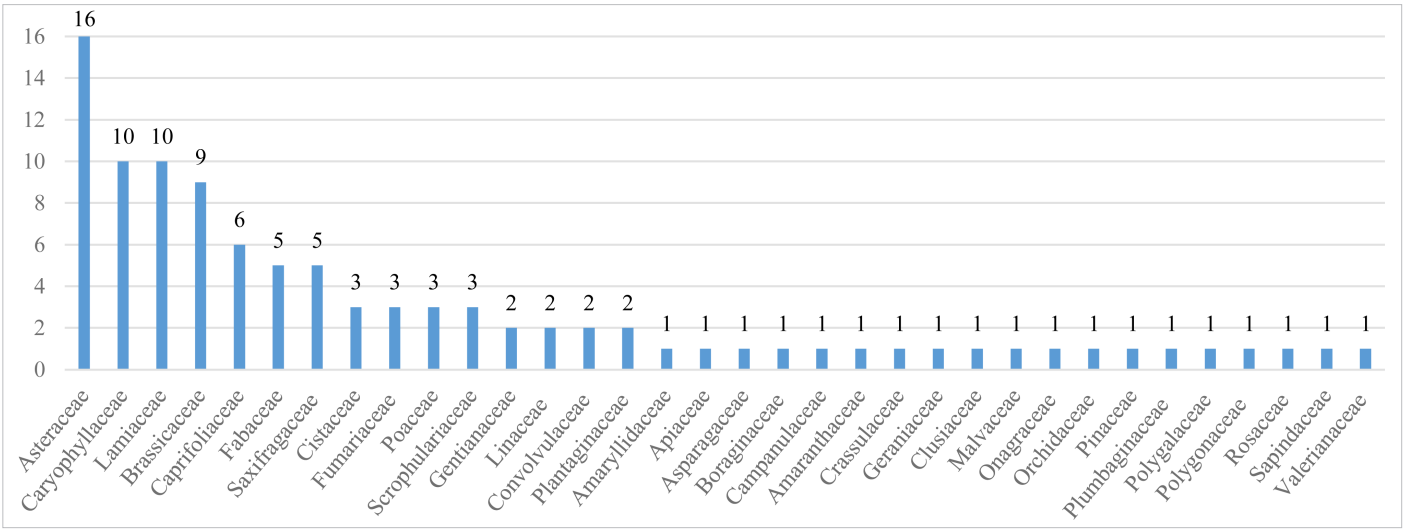

Figure 3.
Number of Taxa (Flora) per Family in the TNP.

Furthermore, although rare species are often threatened, some species with very restricted or infrequent distributions are not necessarily at risk of disappearing, while others that are perceived as common may be in sharp decline and thus appear threatened (Figure 6).

Habitat Characterization

Vegetation Belts and Bioclimatic Zones

The park spans four vegetation belts: Below 1000 m in altitude, it contains plains belonging to the Thermo-Mediterranean vegetation belt, with a bioclimate of temperate to humid subhumid type. There are 42 strict endemic taxa present in this zone. This belt is followed by the Meso-Mediterranean belt, which ranges from 1000 to 1400 m, where 27 strict endemic taxa are found in a humid, cool, or locally perhumid, cool bioclimate. Between 1400 and 1800 m, the supra-Mediterranean belt, the richest in terms of strict endemism, hosts 54 taxa in a perhumid, cold bioclimate. Beyond 1800 m, up to the highest points of the park, the Mountain Mediterranean belt is found, with a very cold perhumid bioclimate, home to 32 strict endemic taxa (Figures 7 and 8).

The altitudinal distribution shows that 05 taxa are indifferent to altitude and can be found across all vegetation belts, 41 taxa are found at variable altitudes but are limited to two or three belts, while 35 taxa are strictly linked to a single vegetation belt.

Exposure

Analysis of the exposure map reveals that 63 taxa occupy the northern slopes, which are colder, less sunny, and better watered; 78 taxa are found on southern slopes, and 54 taxa are located on eastern or western slopes. Strictly endemic taxa that are linked to only one exposure are 26 in total, with nine and five located on the north and west slopes, respectively, 11 on the south slopes, and only one taxon on the east slope. The remaining 56 taxa do not have specific exposure requirements (Figures 9 and 10).

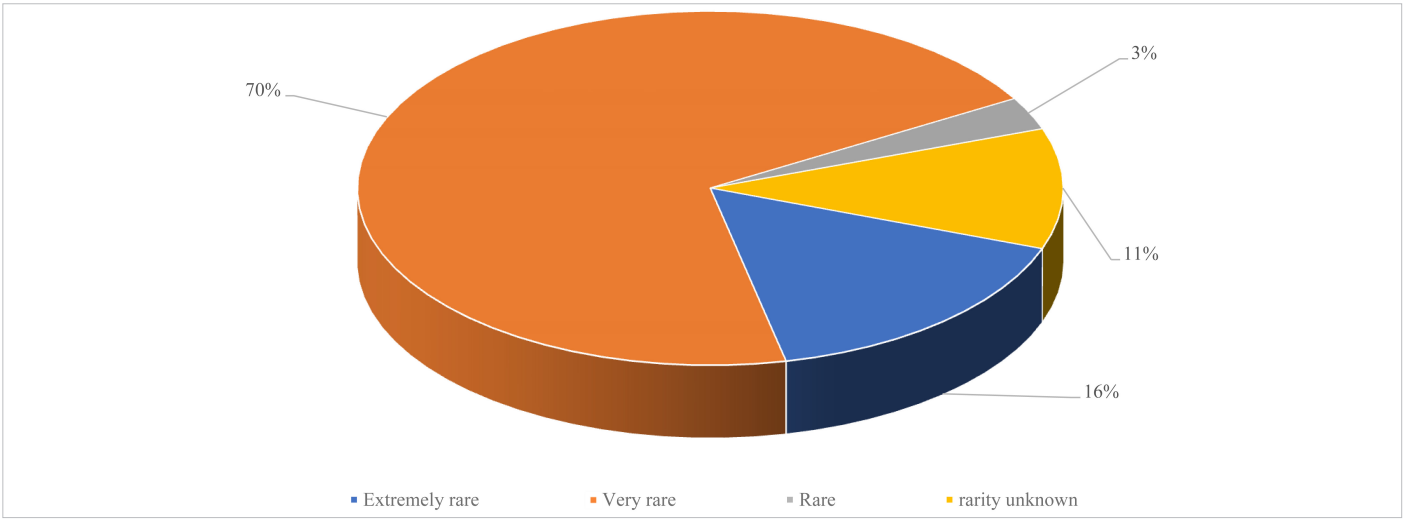

Figure 4.
Percentage of Taxa (Flora) by Degree of Rarity in the TNP.

Table 1.
Clustering of Endemic Taxa by Class in the TNP

Class 1	Class 2	Class 3
Eryngium mohamedanii, *Carduus martinezii* subsp. *fontqueri*, *C. martinezii* subsp. *martinezii*, *Cirsium maroccanum*, *Echinops spinosus* subsp. *fontqueri*, *Ptilostemon rhiphaeus* var. *rhiphaeus*, *Ptilostemon rhiphaeus* var. *tetauense*, *Rhodanthemum laouense*, *Iberis carnosa* subsp. *rhomarensis*, *I. grosmiquelii* var. *grosmiquelii*, *I. nazarita* subsp. *maroccana*, *Raffenaldia primuloides* subsp. *riphaensis*, *Lepidium alpinum* subsp. *hutchinsia*, *L. heterophyllum* subsp. *rifanum*, *Arenaria grandiflora* subsp. *gomarica*, *A. modesta* var. *africana*, *Dianthus anticarius* subsp. *maroccanus*, *Moehringia glochidisperma*, *Paronychia maroccana*, *Silene abietum*, *S. cuatrecasasii* var. *cuatrecasasii*, *S. ibosii*, *S. martyi*, *Polycnemum fontanesii* subsp. *maroccanum*, *Halimium atriplicifolium* var. *macrocalycinum*, *H. lasiocalycinum* subsp. *rhiphaeum*, *Fumana fontqueri*, *Convolvulus vidalii*, *C. mazicum*, *Sedum maireanum*, *Cephalaria leucantha* var. *fragosoana*, *Saxifraga tricrenata*, *Scabiosa turolensis* subsp. *maroccana*, *S. grosii* var. *africana*, *Anthyllis vulneraria* subsp. *fatmae*, *Cephalaria mauritanica* subsp. *rifana*, *Scabiosa turolensis* subsp. *weyleri*, *Astragalus incanus* subsp. *fontianus*, *Vicia lecomtei* subsp. *embergeri*, *Teline osmariensis*, *Fumaria macrosepala* subsp. *obscura*, *F. ouezzanensis* subsp. *ramosa*, *Centaurium pulchellum* subsp. *grandiflorum*, *Marrubium fontianum*, *M. heterocladum* var. *microdontum*, *Origanum grosii*, *Origanum x fontqueri*, *Salvia interrupta* subsp. *paui*, *Teucrium embergeri*, *Stachys fontqueri*, *Linum austriacum* subsp. *gomaricum*, *L. villarianum*, *Globularia liouvillei* subsp. *greuteri*, *Antirrhinum valentinum* subsp. *martenii*, *Armeria masguindalii*, *Bromus erectus* subsp. *permixtus*, *Festuca rifana*, *Polygala rupestris* subsp. *fontqueri*, *Polygonum balansae* subsp. *rhizoxylon*, *Potentilla caulescens* subsp. *achhali*, *Acer granatense* subsp. *xauense*, *Saxifraga maweana*, *Saxifraga rigoi* subsp. *maroccana*, *Saxifraga tricrenata*, *Digitalis laciniata* subsp. *riphaea*, *Scrophularia eriocalyx* var. *foliosa*, *Verbascum faurei* subsp. *acanthifolium*, *Fedia graciliflora* subsp. *snassenorum*, *Onosma fastigiata* var. *maroccana*.	*Eryngium mohamedanii*, *Carduus martinezii* subsp. *martinezii*, *Centaurea carolipauana* Fdez. Casas & Susanna, *Ptilostemon rhiphaeus* var. *tetauense*, *Rhodanthemum hosmariense*, *R. laouense*, *Senecio perralderianus* subsp. *hosmariense*, *Iberis nazarita* subsp. *maroccana*, *Arenaria grandiflora* subsp. *gomarica*, *A. modesta* var. *africana*, *Dianthus anticarius* subsp. *maroccanus*, *Paronychia maroccana*, *Polycnemum fontanesii* subsp. *maroccanum*, *Halimium atriplicifolium* var. *macrocalycinum*, *Convolvulus vidalii*, *C. mazicum*, *Scabiosa turolensis* subsp. *maroccana*, *Anthyllis vulneraria* subsp. *fatmae*, *Vicia lecomtei* subsp. *embergeri*, *Fumaria macrosepala* subsp. *obscura*, *Erodium heteradenum*, *Origanum grosii*, *Stachys fontqueri Pau*, *Teucrium embergeri*, *Linum villarianum Pau*, *Festuca rifana*, *Potentilla caulescens* subsp. *achhalii Romo*, *Acer granatense* subsp. *xauense*, *Saxifraga rigoi* subsp. *maroccana*, *Saxifraga tricrenata*, *Saxifraga werneri*, *Digitalis laciniata* subsp. *riphaea*, *Muscari grandifolium* var. *rifanum*.	*Carduus martinezii* subsp. *martinezii*, *Centaurea xaverii*, *Ptilostemon rhiphaeus* var. *rhiphaeus*, *Ptilostemon rhiphaeus* var. *tetauense*, *Rhodanthemum laouense*, *Senecio perralderianus* subsp. *hosmariense*, *Iberis carnosa* subsp. *rhomarensis*, *I. grosmiquelii* var. *grosmiquelii*, *I. lagascana* subsp. *lagascana*, *Lepidium hirtum* subsp. *afrum*, *Jasione crispa* subsp. *cedretorum*, *Moehringia akchourii*, *Paronychia maroccana*, *Silene abietum*, *S. cuatrecasasii* var. *cuatrecasasii*, *S. ibosii*, *Halimium atriplicifolium* var. *macrocalycinum*, *Cephalaria leucantha* var. *fragosoana*, *Scabiosa grosii* var. *africana*, *S. turolensis* subsp. *maroccana*, *S. turolensis* subsp. *weyleri*, *Astragalus incanus* subsp. *fontianus*, *Vicia lecomtei* subsp. *embergeri*, *Fumaria macrosepala* subsp. *obscura*, *Centaurium erythraea* subsp. *bifrons*, *Marrubium fontianum* Maire, *Origanm grosii*, *Origanum x fontqueri*, *Stachys fontqueri*, *Teucrium embergeri*, *Teucrium rotundifolium* subsp. *sangusorbiflorum*, *Armeria masguindalii*, *Polygala rupestris* subsp. *fontqueri*, *Acer granatense* subsp. *xauense*, *Saxifraga x fontqueri* Romo, *S. werneri* , *Digitalis laciniata* subsp. *riphaea*, *Fedia graciliflora* subsp. *snassenorum*.

Soil Types

The growth of the taxa subject to this study occurs on a wide variety of soil types, which are distinguished by their stage of evolution or by the presence or absence of certain mineral elements. The most dominant soil type in the park is Rendzic. This is a soil with high levels of total calcium compared to other soils and exhibits an early stage of humification blocking, supporting 31 taxa. Despite the relatively small area occupied by Arenosol and Cambisol compared to Rendzic, we observed that a large number of strict endemic taxa are found on these two soil types. Arenosol is a sandy, very permeable soil that is minimally affected by excess water, supporting 57 taxa, while Cambisol is a more evolved forest soil that hosts 50 taxa. Other soil types, such as Luvisol, considered a leached soil with deficiencies in calcium, magnesium, and potassium, support nine taxa, and Regosol, a poorly evolved soil, hosts four taxa (Figures 11 and 12).

Statistical analysis shows that 47 taxa are indifferent to soil types, while the remaining 35 taxa are more specific in terms of edaphic requirements and are limited to a single soil type.

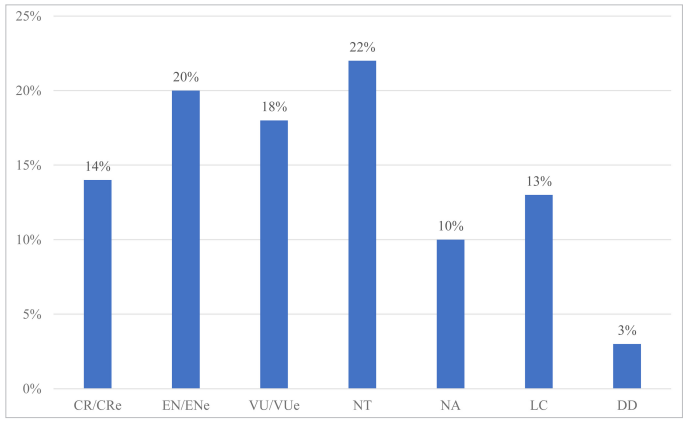

Figure 5.
Percentage of Taxa (Flora) per Conservation Status in the TNP.

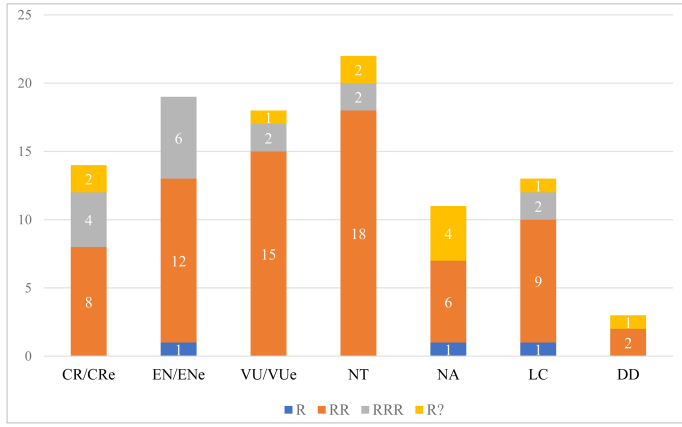

Figure 6.
Number of Taxa (Flora) by Rarity and Conservation Status in the TNP. (R = Rare; RR = Very rare; RRR = Extremely rare; R? = Unknown rarity).

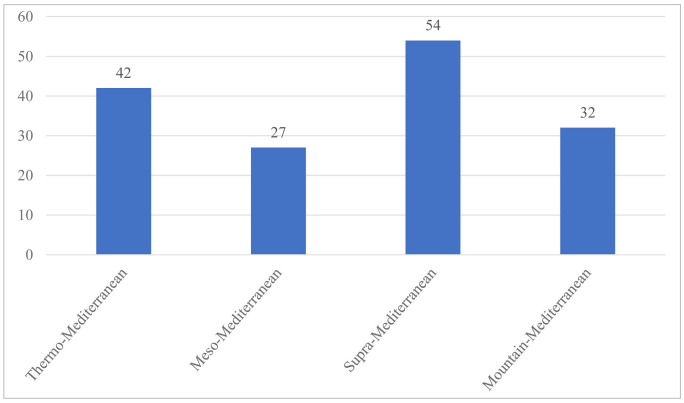

Figure 7.
Number of Taxa (Flora) per Vegetation Belt in the TNP.

Stand Type

Talassemtane National Park contains a diversity of ecosystems characterized by key forest species that form stands either in pure form or mixed with other secondary species. For the localization of endemic taxa, we took into account the main species that characterize each stand type. Specifically, we identified 59 taxa in the maquis, 49 under the holm oak (*Quercus rotundifolia* Lam.), 33 taxa in the stands of Moroccan fir (*A. marocana*), 18 in the stands of maritime pine (*P. pinaster* var. *maghrebiana*), seven under the thuya (*T. articulata*), three taxa under kermes oak (*Quercus coccifera*), two under coniferous reforestation (C. reforestation), and a single taxon under Atlas cedar (*Cedrus atlantica*) (Figures 13 and 14).

The relationship between all the habitats of the studied strict endemic taxa was confirmed by cluster analysis conducted on the ecological variables and the studied taxa. The results are presented as a dendrogram (Figure 15) with three classes of taxa, each showing relatively distinct ecological significances. The first class includes the majority of taxa (67), which are indifferent to the studied ecological variables and, as such, these taxa are found throughout the park. The second and third classes include 33 and 38 taxa, respectively. Each of these two classes is associated with one or two ecological factors, meaning that their presence is relatively conditioned by the required environmental factors (Table 1).

Discussion

The bibliographic review allowed us to compile a list of 340 endemic taxa, of which 100 are strictly endemic to the park and its surroundings. Benabid (2008) identified 314 endemic taxa, with 86 strictly endemic to the park and its surrounding areas. However, other studies conducted

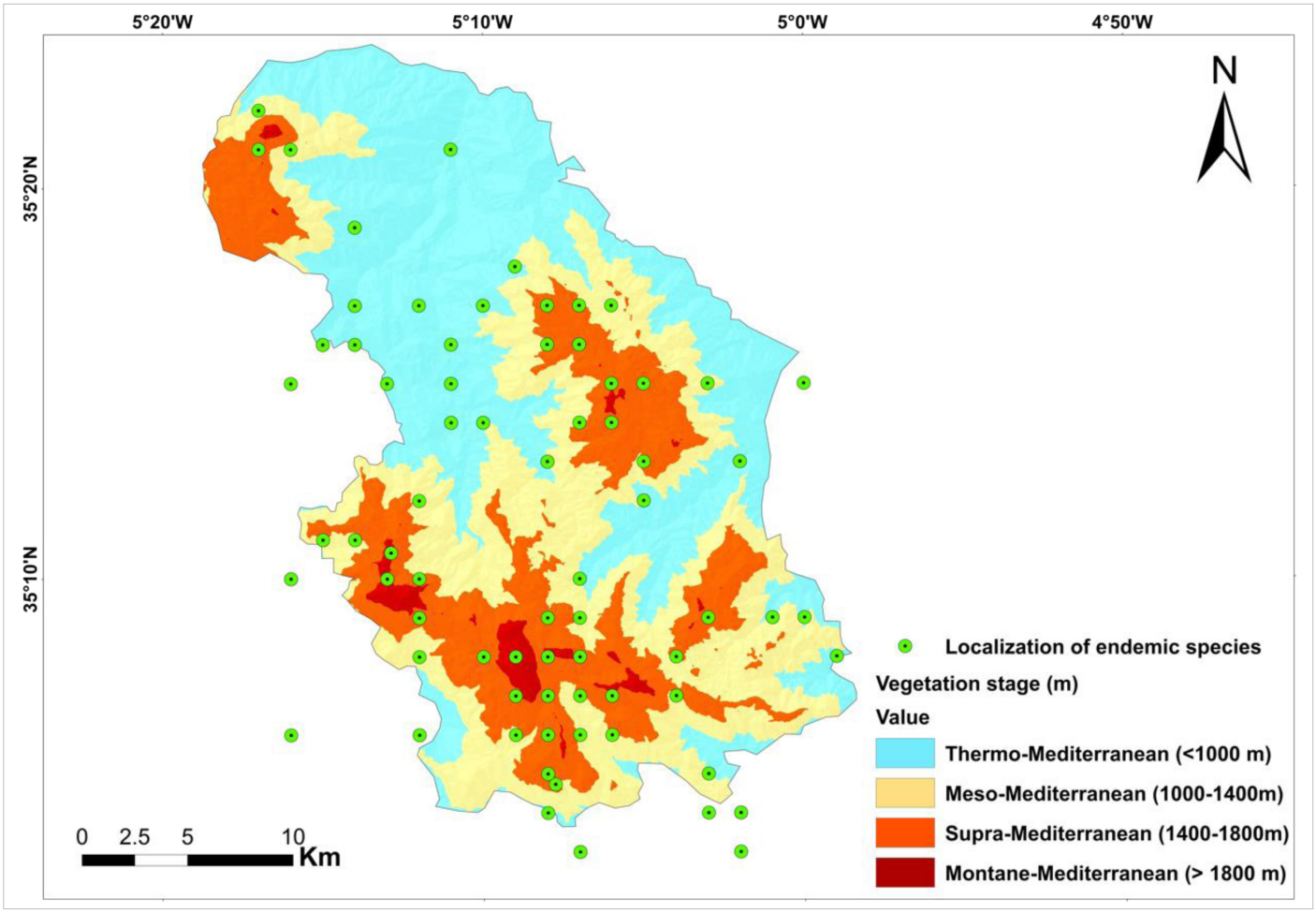

Figure 8.
Spatial Distribution of Taxa per Vegetation Belt in the TNP.

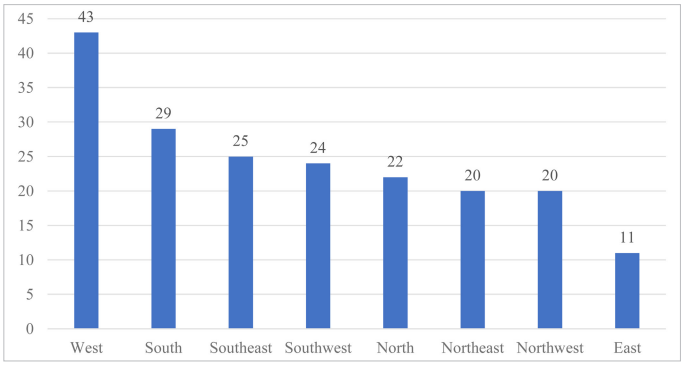

Figure 9.
Number of Taxa (Flora) per Exposure in the TNP.

in the western Rif (Dobignard, 2009; Fennane et al., 1999–2014; Mateos & Valdés, 2006, 412009, 42) enabled us to identify the remaining taxa.

Certainly, there is always an interdependence between the ecological factors of ecosystems and the living organisms within them. However, the requirements of species in relation to one or more of these factors are often determinant for their distribution (Laaribya et al., 2021; Laaribya et al., 2023). Moreover, the examination of the relationships between vegetation and ecological variables shows that the strict endemic taxa of the park can be classified into three ecological classes: The first class includes the majority of taxa that are indifferent to the studied ecological variables, while the second and third classes group taxa with affinities to one or two ecological factors. These are taxa whose presence is relatively conditioned by the required environmental factors. Our results confirm those of Aafi (1995) regarding the identification of ecological factors influencing the distribution of taxa and floristic composition. Indeed, several examples illustrate this distribution by affinity; *Silene cuatrecasasii* Pau & Font Quer var. *cuatrecasasii* and *Iberis carnosa* subsp. *rhomarensis* (J.M. Monts-Martí) Valdés & Mateos are found in all vegetation belts, i.e., at different altitudes and in various bioclimates, on three types of soils, different stand types, and all exposures. The location of *Saxifraga rigoi* Porta subsp. *maroccana* Luizet & Maire on south-facing slopes at altitudes between 1500 and 1800 meters shows its affinity for the supra-Mediterranean belt and sun-exposed slopes. *Eryngium mohamedanii* and *Convolvulus vidalii* Pau are also examples of taxa with ecological affinities: the former is linked to the holm oak stand, while the latter is associated with the arenosol soil type. Moroccan fir is an example of a taxon whose exclusive and limited presence is conditioned by a combination of edaphic and climatic factors (Alaoui et al., 2021), as it is only found in the supra- and montane-Mediterranean belts on north-facing slopes and on limestone and brown forest soils.

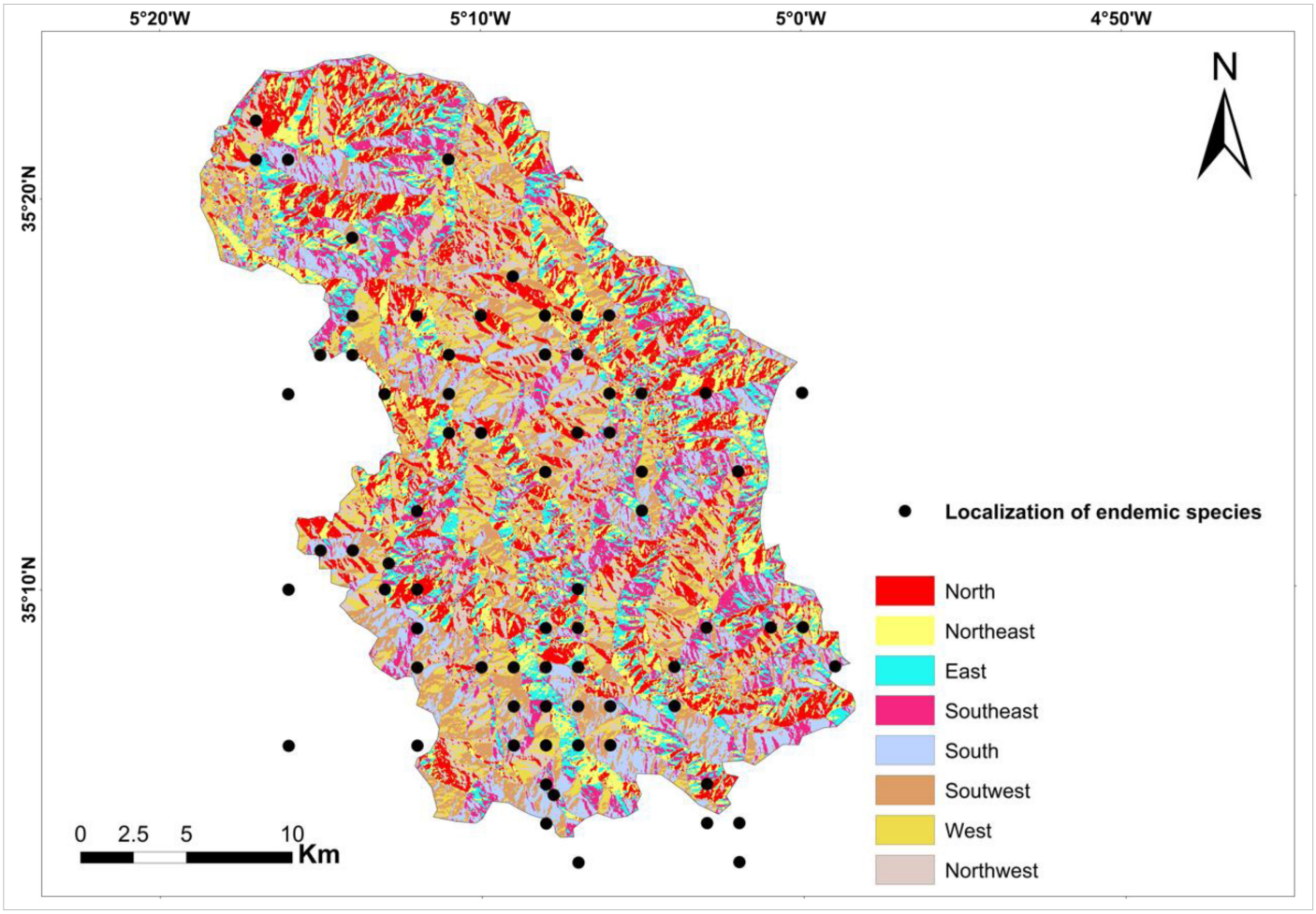

Figure 10.
Spatial Distribution of Taxa (Flora) by Exposure in the TNP.

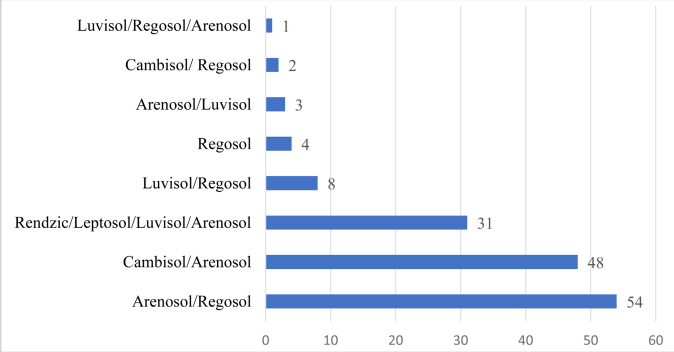

Figure 11.
Number of Taxa (Flora) per Soil Type in the TNP.

Thus, based on field surveys, we found that the majority of strictly endemic taxa (62 taxa) are located in high-altitude areas above 1400 meters and in cold and very cold perhumid bioclimates, coinciding with the protected natural area where all forms of resource exploitation or collection are prohibited, and the managed natural sanctuaries where resource exploitation activities are still permitted. These two areas cover the range of Moroccan fir stands in pure form or mixed with other species and holm oak stands. The latter are the most widespread in the park, occurring across all vegetation belts from thermo-Mediterranean to montane-Mediterranean, but it is in the supra-Mediterranean and montane-Mediterranean belts that holm oak stands host the highest number of endemic taxa. We also observed the absence of 18 taxa. The hypothesis of their extinction is strong and justified, on the one hand, by the rarity of these taxa and, on the other hand, by deforestation, which generally affects areas where resource exploitation is allowed, particularly the peripheral zone of the Park. Among the many direct causes of forest degradation in the Park, deforestation for *Cannabis sativa* cultivation and wood cutting for firewood represent nearly 90% of the deforestation process (Grovel, 28). The study by Beroui (12) highlights that between 1995 and 2019, an area of 4857 ha of forest cover and maquis declined in favor of crops with various purposes (*cannabis*, cereals, etc.). The same author reports that 607 ha of forested areas composed of various species were destroyed by fires during the same period, and over 530 ha of holm oak were converted into maquis. Castro et al. (15) reported a loss of forest due to an average of 278 ha burned annually in the TNP. Moreover, excessive and uncontrolled forest grazing considerably hinders species regeneration in the park and contributes to the disappearance of others (Benabid, 1982), especially in the current context where climate change further exacerbates biodiversity loss (Azedou et al., 2024).

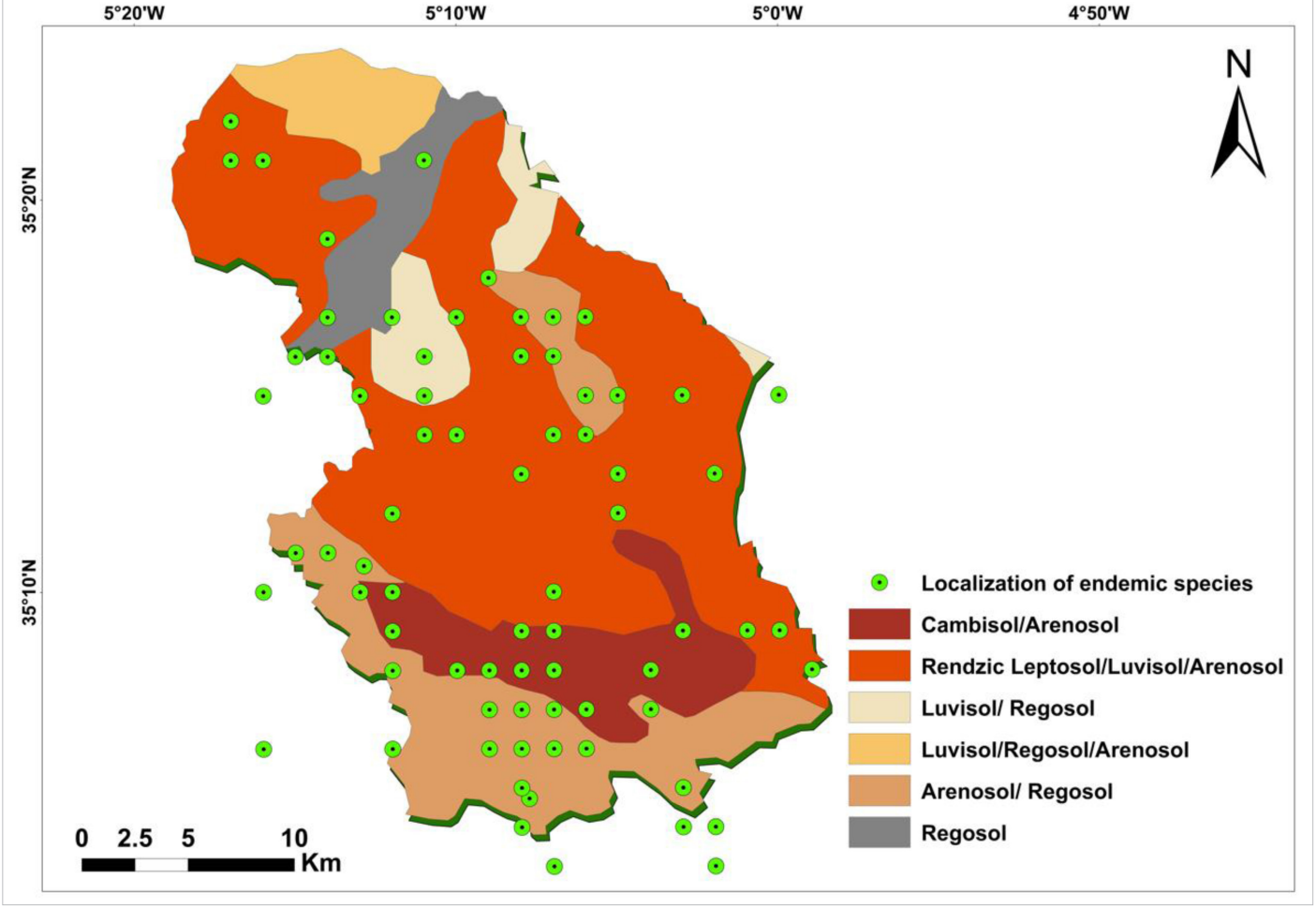

Figure 12.
Spatial Distribution of Taxa (Flora) per Soil Type in the TNP.

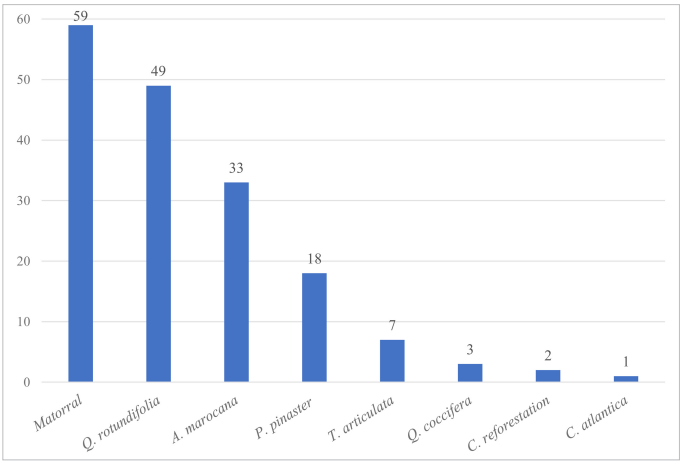

Figure 13.
Number of Taxa (Flora) per Stand Type in the TNP.

From the perspective of the forest ambiance linked to the stand type where each studied taxon is located, we were able to identify 59 strictly endemic taxa in the maquis. These Mediterranean-type plant formations represent the ultimate state of ecosystem degradation, as their resilience capacities are likely no longer manifesting naturally, or are extremely slow and difficult to recover. Furthermore, we detected that 28 of these taxa are still found under relatively conserved original tree stands, while there is a high risk of extinction for the 31 taxa restricted to the maquis. This concerning observation urges us to sound the alarm about the significant risk of losing this original biodiversity, as maquis are easily cleared and could be converted into agricultural or residential areas in the short or medium term.

Although some taxa are considered to be in a worrying situation and others in an alarming one, when considering their rarity status and the direct threats to their existence, the conservation status assessment by the IUCN, considered the most widely accepted and used authority for biodiversity conservation status (Hayward, 2009), covers only 29 of these taxa.

Conclusion and Recommendations

Talassemtane National Park is a key region for plant diversity in Morocco, hosting around one 420 plant species. Of these, 24% are endemic, with 100 species strictly limited to the park and its surrounding areas, making up 7% of its vascular flora. The habitats of these strictly endemic species have been studied and compared, with various environmental factors such as altitude, soil types, bioclimates, exposures, and vegetation types

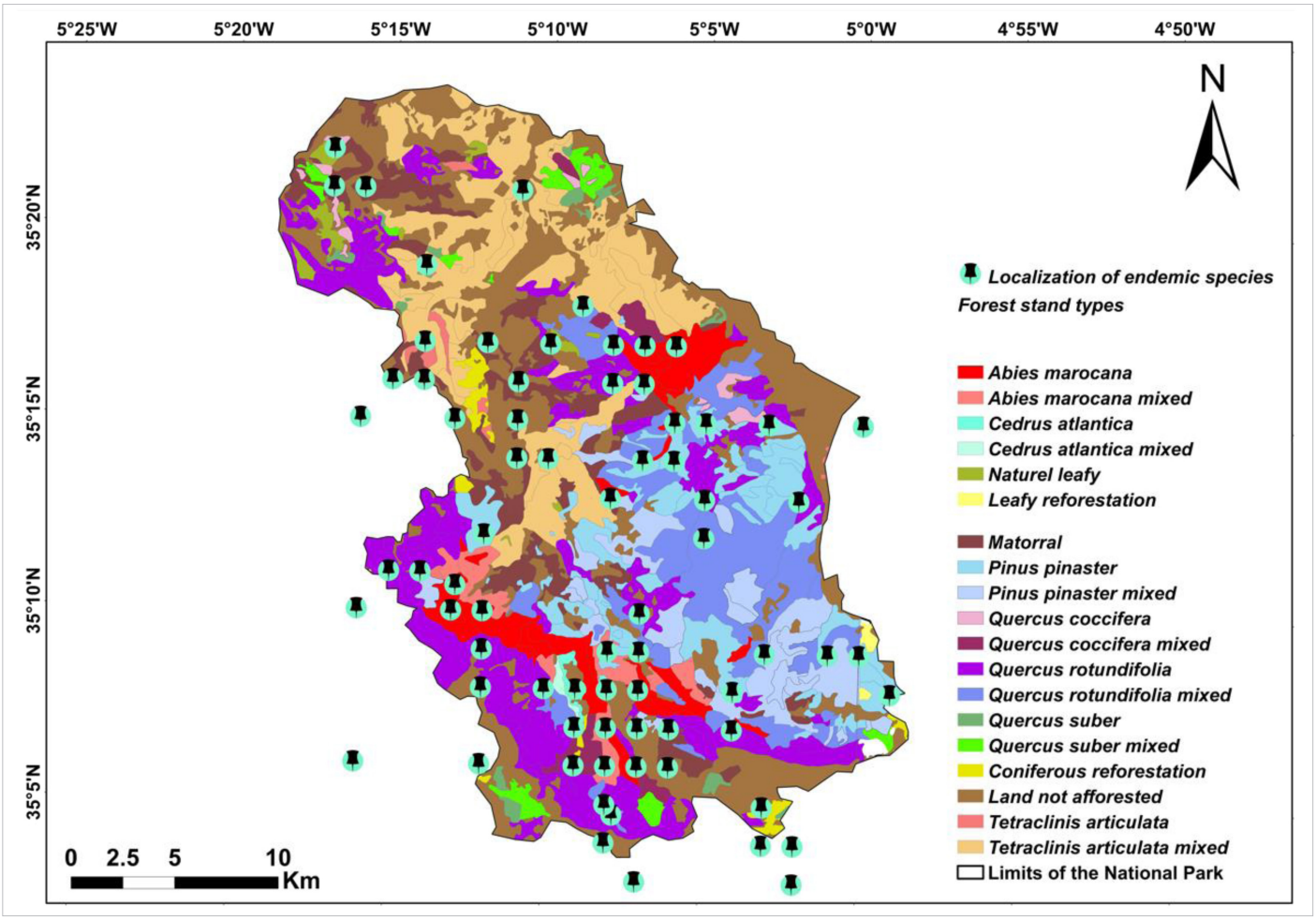

Figure 14.
Spatial Distribution of Taxa (Flora) per Stand Type in the TNP.

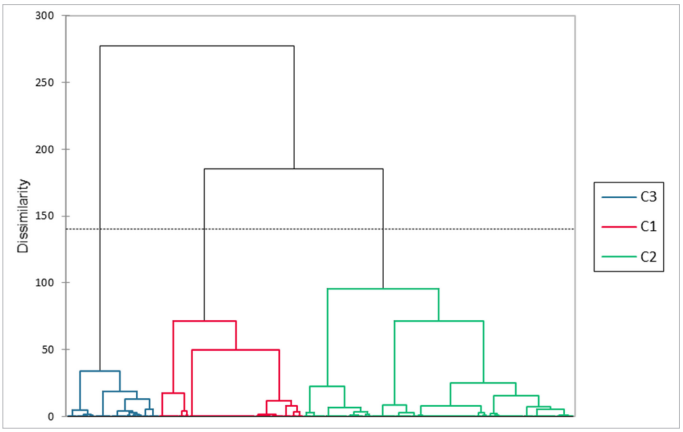

Figure 15.
Cluster Analysis Based on the Endemic Taxa (Flora) in the TNP (C1 = Class 1; C2 = Class 2, C3 = Class 3).

all contributing to the characterization of their habitats. These factors highlight the significant floristic and ecosystem diversity present in the park. Based on the findings and field observations, it is evident that various threats are impacting plant biodiversity, particularly some of the Park's endemic species. Therefore, assessing the conservation status of these endemic species should be a top priority in order to implement protective measures for the vulnerable species and delicate habitats within the Park.

Data Availability Statement: The data that support the findings of this study are available on request from the corresponding author.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept – A.A., S.L.; Design – A.A., S.L.; Supervision – S.L., S.A.; Resources – A.A.; Materials – A.A., S.L.; Data Collection and/or Processing – A.A., S.L.; Analysis and/or Interpretation – A.A., S.L., S.A.; Literature Search – A.A.; Writing Manuscript – A.A., S.L., S.A.; Critical Review – A.A., S.L., S.A.; Other – A.A., S.L.

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