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Phytogeographic Transition Areas Hide Floristic Diversity in Hyper-Arid Environments (Sharaan Natural Reserve, NW-Saudi Arabia)

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Abstract: Phytogeographic transition zones are often considered areas rich in biodiversity due to their ecological and landscape diversity. This study constitutes the first floristic investigation of the Sharaan Natural Reserve (SNR) located in the northwest of the KSA, which is supposed to be a phytogeographic transition zone due to its location between the central zone of the country dominated by Saharo-Arabic flora and the northern zone characterized by a Mediterranean and Irano-Turanian floristic affinities. The floristic studies carried out in the vegetation season from 2022 to 2024 led to the identification of 166 plant taxa belonging to 38 botanical families. The flora of the SNR is dominated by Therophytes, while the Saharo-Arabian element dominates the chorology of the taxa. The comparative phytogeographic analysis of SNR flora compared to the available literature on published floristic inventories in different phytogeographic regions of the country has confirmed the floristic affinities of the flora of the reserve, especially with the northern and Nefud regions. Among the identified plants, 13 taxa were not mentioned in the 44 consulted references and seem more or less exclusive to the reserve/phytogeographic region. Also, 12 taxa are considered of Least Concern according to the IUCN red list while the presence of *Calligonum comosum* L'Hér. allows the classification of its natural habitat (dunes) as a Critical Habitat according to the PS6 criteria. This study reports that SNR constitutes a phytogeographic and floristic transitional area by the presence of a significant number of Irano-Turanian (43) and Mediterranean (21) taxa mixed with the dominant Saharo-Arabic species. The SNR region contains a rich and diverse flora due to the biogeographical situation as a transitional zone and the protection due to the closure. This conservation should be strengthened and extended to other neighboring areas with the same biological wealth.

Keywords: AlUla county; biogeography; chorology; flora; mediterranean; protected areas; Saharo-Arabian

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1. Introduction

The Kingdom of Saudi Arabia (KSA) is the largest country in the Arabian Peninsula, with an area exceeding 2.5 million km^2 [1]. This country, dominated by the great Arabian desert with a harsh hyper-arid climate, is, in reality, rich in animal and plant biodiversity [2,3]. This biological richness comes mainly from the geographical, ecological, and landscape diversity that exists in this country, allowing for the existence of a rich and abundant fauna and flora [4,5].

The flora of Saudi Arabia has been mainly studied by Mighaid [6], Chaudhary [7,8], Chaudhary and Al-Jowaid [9], and Collenette [10,11] but without proposing a complete and exhaustive document reporting all the necessary information on the flora, especially the details regarding the taxonomy, chorology, and biogeography of the taxa. According to Collenette [10], the flora of the KSA includes 2250 taxa belonging to 835 genera and 142 families. However, this number has changed since then, and actually, we do not have reliable, verified, and updated data on these flora, despite the range of local and regional floristic inventory and investigation work that has recently been published, including those of Abdein and Osman [12], Qari et al. [13], Obaid and Abdel-Hameed [14], Fadl et al. [15], Ghazal [16], Ansari et al. [17], Al-Namazi et al. [18], Al-Quahtani et al. [19], Al Masoudi [20]. These studies reported valuable information on the taxonomy, biogeography, and uses of plants in the KSA, but they still failed to cover the entire country. More studies are needed to explore the floristic diversity of this big country [21].

Regarding taxonomy, except for a few unofficial websites (https://plantdiversityofsaudiarabia.info/; https://floraofksa.myspecies.info/; accessed on 12 October 2024) reporting some non-exhaustive checklists, no reference reports a complete and updated list of the country's flora in light of recent taxonomic revision work. Thus, there are still some botanical gaps, as well as a certain number of taxonomic and synonymic confusions that are visible in recently published regional works [21].

Regarding biogeography, it is accepted that despite the dominance of hyper-arid desert environments, the country remains biogeographically quite contrasted, particularly by the existence of several ecosystems in the south of the country, on the shores of the Red Sea and in the north near the borders with Jordan [22]. Furthermore, new biogeographic records of plant taxa continue to be reported through the analysis of previous works and/or regional exploration works [21,23–30], which indicates a certain lack of knowledge of the flora of the KSA. Despite the fact that all these works reported more than 15 taxa of plants new to the country, Al-Khulaidi et al. [30] specified that the number of discovered taxa in the KSA remains low, and this is mainly due to the lack of exploration works. Indeed, it has been observed that several zones of the country, including some protected areas, have not been explored in terms of flora, and consequently, no knowledge is available on the flora of these regions as well as its taxonomic, chorological, and biogeographical characteristics.

Protected areas represent an important tool for the conservation of natural biodiversity, particularly in arid environments [31]. Recently, particular attention has been given to the conservation issue of biodiversity and natural ecosystems in the KSA through the creation of several nature reserves across vast areas within the country [32]. However, like many floristically important areas in the KSA, the data available on the local flora and their characteristics remain limited or even non-existent [21,33]. This is the case of The Sharaan Nature Reserve (SNR), located in AlUla County (NW KSA), which was created in 2020 with the main objective of protecting biodiversity from human activities, including grazing, car off-road driving, plastic pollution, and agriculture. This protected area, benefiting from a complete closure of its space since 2020 in order to restore the original flora and fauna, is likely to contain rich and diverse flora due to its geographical location, making a transition between the hyper-arid center regions and the less arid north areas of the country where

the influence of Mediterranean and Irano-Turanian chorological elements starts to appear. These biogeographic transition zones often contain high biological diversity [34], but this has not been observed everywhere [35].

Through this study, we suggest that the geographical location of SNR as a transitional phytogeographical area allows it to contain a diverse flora on the taxonomic and chorological level, which makes it a true floristic transition zone in the KSA.

Thus, the present study will aim to explore the flora of the Sharaan Nature Reserve by analyzing its taxonomic, chorological, and biogeographical characteristics. The analysis of this flora will report some unpublished data reinforcing knowledge of KSA flora.

2. Material and Methods

2.1. Study Area

This work was carried out in the Sharaan Nature Reserve (SNR) in AlUla County, located in the northwest of Saudi Arabia. This protected area has been granted protected status and remains managed by the Royal Commission for AlUla (RCU) as part of the conservation of biodiversity in line with the objectives of Saudi Arabia's Vision 2030. The reserve covers an area of 1500 km^2 (579 mi^2) of steep red rock canyons, sprawling deserts, and valleys carpeted with delicate wildflowers, offering a treasure trove of natural biodiversity. It has been fully fenced since 2020 to combat any external disturbance. It lies in a hyper-arid climate with an average annual rainfall of 50 mm, which occurs mainly in occasional thunderstorms between November and February. The mean annual temperature ranges from 4 °C to 38.9 °C (mean 28.4 °C), with significant fluctuations between winter and summer (meteostat.net), while the mean annual wind speed is 10.4 km/h. Soils are mainly sandy, formed up to 1.5 m depth on Cambrian sandstone formations. For this study, a 25 km^2 pilot site area, representative of the SNR environment, was selected, encompassing the 150 survey points (Figure 1) in addition to the other observations.

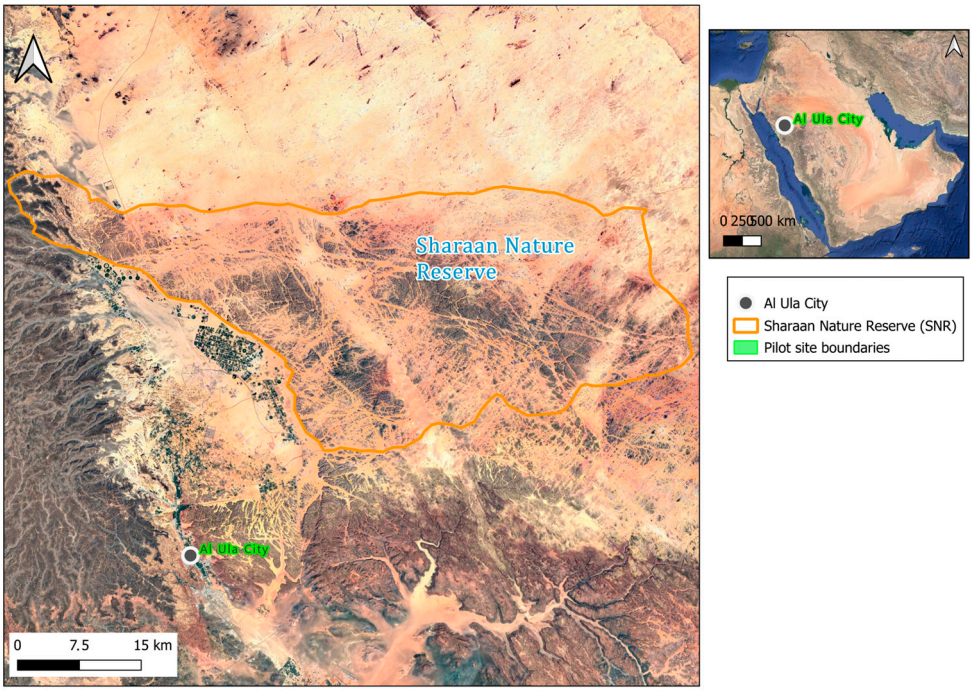

Figure 1. Location of the study area.

2.2. Data Collection and Analysis

Multiple sampling methods were applied through several projects carried out in the study area as part of the reserve restoration strategy adopted by the Royal Commission for AlUla.

In fact, the Sharaan Nature Reserve (SNR) was created in 2020 to preserve local biodiversity against increased anthropogenic actions such as overgrazing and agriculture. Many plots of land have been extensively cultivated in the past as oases and/or other local market garden crops, which has affected all existing natural habitats within the reserve.

Data obtained from 150 floristic surveys as well as 192 sentinel sites located only in natural habitats (*Vegetated red sandstone foot cliff; Species rich open shrubland formation and Sandy open environment*) were used to propose a first checklist of the flora of SNR (Figure 2).

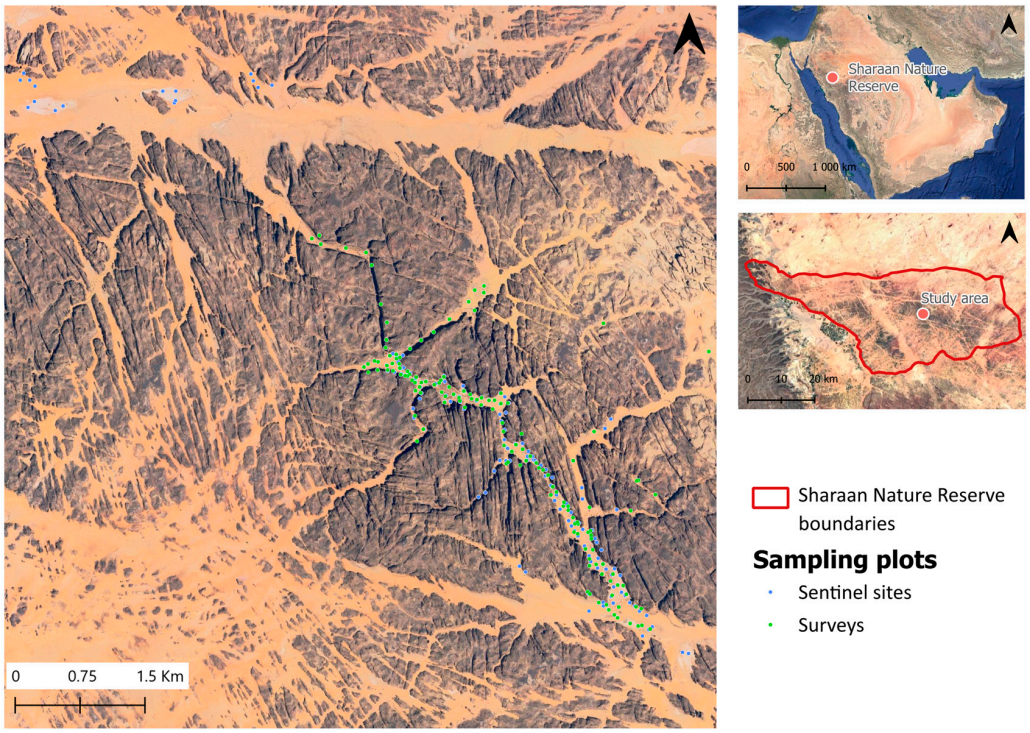

Figure 2. Location of vegetation samples in the study area.

Floristic surveys consisted of circular plots of 50 m^2 (for a 3.99 m radius circle) [36,37], while sentinel sites have been installed throughout the reserve (1 × 1 m^2) to long-term monitor the vegetation of the reserve. Regular inventories (every fall/spring between 2022 and 2024) are carried out at the plots. Indeed, fieldwork was planned in different seasons of the year over a period of 4 years in order to sample as many floristic taxa as possible.

Furthermore, many free field observations were combined to enhance the inventory of the reserve flora. Due to the ban on picking within the reserve, a collection of photographs of plants recorded in the field was carried out as part of this work. Identifications were made using the available literature [7–11,38], while the nomenclature of the identified taxa was verified and updated through the Royal Botanic Garden of Kew database (https://powo.science.kew.org/ accessed on 9 October 2024). For the definition of life forms and chorotypes, the following documentation was used: Zohary [39–41], White and Leonard [42], Boulos [38], and Al-Nafie [22].

The analysis of the geographical distribution of taxa in the KSA was carried out using the published literature for this purpose, in particular Migahid [43], Collenette [10,11], and Chaudhary [7,8], and all the research papers available on the accessible databases in internet (Google scholar, Scopus, PubMed, Science direct, etc.). A total of 43 papers representing

various regions of the Country and reporting local or regional floristic inventories were selected and consulted. We also considered the localities of the plant taxa reported in Collennette [10].

The localities of the floristic taxa cited in the consulted studies were categorized according to the main phytogeographic regions of the KSA [44] (Figure 3). The precise locations obtained from the studies and Google Maps led to assigning each of the localities to one or several phytogeographic regions (Table 1). The presence/absence data matrix was constructed from these data, placing the taxa in columns (166 taxa) and the phytogeographic representing 43 locations + 15 locations cited in Collennette [10], including the study area in rows. The matrix was subjected to Non-Metric Multidimensional Scaling (NMS) in order to group the studied locations according to their floristic similarity. The analysis was carried out using PC-ORD. 5. Unlike metric multidimensional scaling, which relies on distance measures that assume a linear relationship between variables, NMS uses rank-order information. This means it focuses on the relative distances between data points rather than their absolute distances, making it suitable for non-linear relationships.

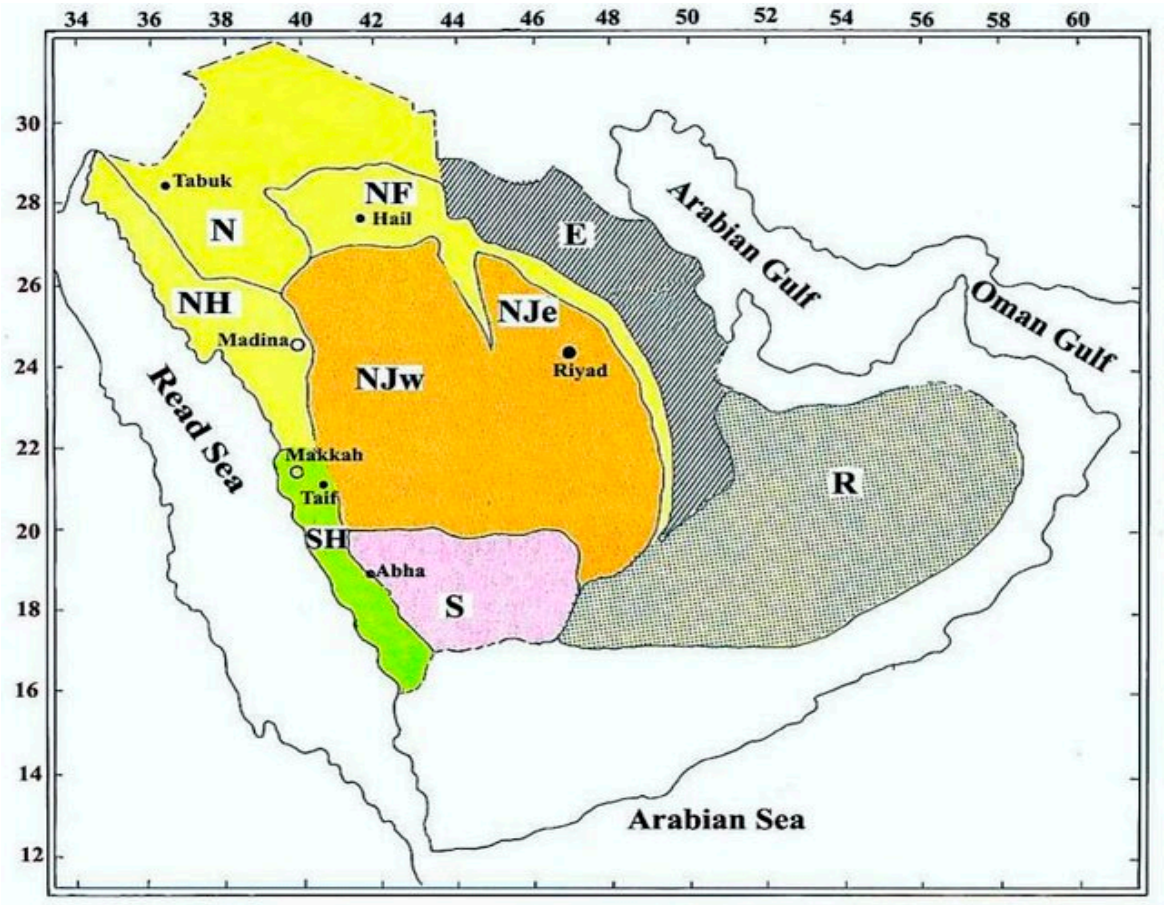

Figure 3. Map showing the different phytogeographical regions of Saudi Arabia (according to Migahid and Hammouda [44]). (NH): North Hejaz; (N): Northern region; (NF): Nefud; (E): Eastern region; (Njw): West Najd; (Nje): East Najd; (SH): South Hejaz; (S): Southern region; (R): Al-Rubi Al-khale.

Table 1. Phytogeographic region of the KSA with corresponding analyzed papers study areas (numbers correspond to citations appearing in Supplementary Table S1).

Phytogeographic Region	Corresponding Analysed Papers Study Areas
North Hejaz (NH)	[3], [4], [21], [41], [44-8]
Northern region (N)	[3], [20], [23], [25], [31], [38], [42], [44-3], [44-14]
Nefud (NF)	[3], [22], [27], [38], [44-5]
Eastern region (E)	[6], [12], [13], [19]
West Najd (Njw)	[1], [26], [33], [35], [38], [44-1], [44-6]
East Najd (Nje)	[2], [10], [11], [16], [17], [22], [33], [36], [39]
South Hejaz (SH)	[5], [7], [8], [14], [15], [24], [28], [29], [32], [34], [40/44], [4/44], [7/44], [10/44], [11/44], [12/44], [13/44], [15-44]
Southern region (S)	[18], [30], [37], [44-2]
Al-Rubi Al-khale (R)	[13], [44-9]

For the analysis of threatened taxa, the IUCN Red List of Threatened Species [45] was used to define the global status of plants, while at the national level, we used the first Saudi Arabian National Report on the Convention on Biological Diversity [46]. These authors use a series of criteria to define the taxa of High Conservation Priority in the KSA. The definition of Critical Habitats based on the threatened species at the global/national scale was performed using the PS6 criteria [47] given in Table 2.

Table 2. Criteria used to define threatened taxa and species for critical habitats.

Criteria Used for the List of Taxa of High Conservation Priority in the KSA (AbuZinada et al., 2004 [46])	
Criterion 1	Genera, species, or subspecies that are critically endangered, endangered, or vulnerable (globally, regionally, or nationally); taxa that are locally extinct in the wild may be included, provided that there is an NCWCD policy to reintroduce them.
Criterion 2	Genera, species, or subspecies that are endemic to the Arabian Peninsula, the Red Sea, or the Gulf.
Criterion 3	Genera, species, or subspecies of which the conservation of populations within Saudi Arabia is essential to the conservation of the taxon (e.g., near-endemics and migrants for which Saudi Arabia represents a critical range).
Criterion 4	Relict genera, species, or subspecies that are of global, regional, or national significance.
Criterion 5	Genera or species of special ecological importance (i.e., fulfilling a vitally important function in an ecosystem, such as providing a key habitat for other species, serving as indicator species, etc.).
Criterion 6	Genera of species of significant economic importance.
Criterion 7	Genera or species that serve a "flagship" function (i.e., high-profile species of cultural value, the protection of which will also protect large numbers of other species that share their habitats).
PS6 criteria for Critical Habitats analyses (IFC, 2012 [47])	
Criterion 1	Critically Endangered (CR) and/or Endangered (EN) species.
Criterion 2	Endemic and/or restricted-range species.
Criterion 3	Migratory and/or congregatory species.
Criterion 4	Highly threatened and/or unique ecosystems.
Criterion 5	Key evolutionary processes.

3. Results

Floristic Composition

Our field investigation allowed us to propose the first inventory of the flora of the Sharaan Nature Reserve. Through this inventory, we have identified 166 plant taxa belonging to 38 different botanical families (Supplementary Table S1). These families are mainly dominated by Asteraceae (28 taxa, 17%), Fabaceae (19 taxa, 12%), Brassicaceae, and Poaceae (14 taxa, 8%) each and Caryophyllaceae (13 taxa, 8%) (Figure 4).

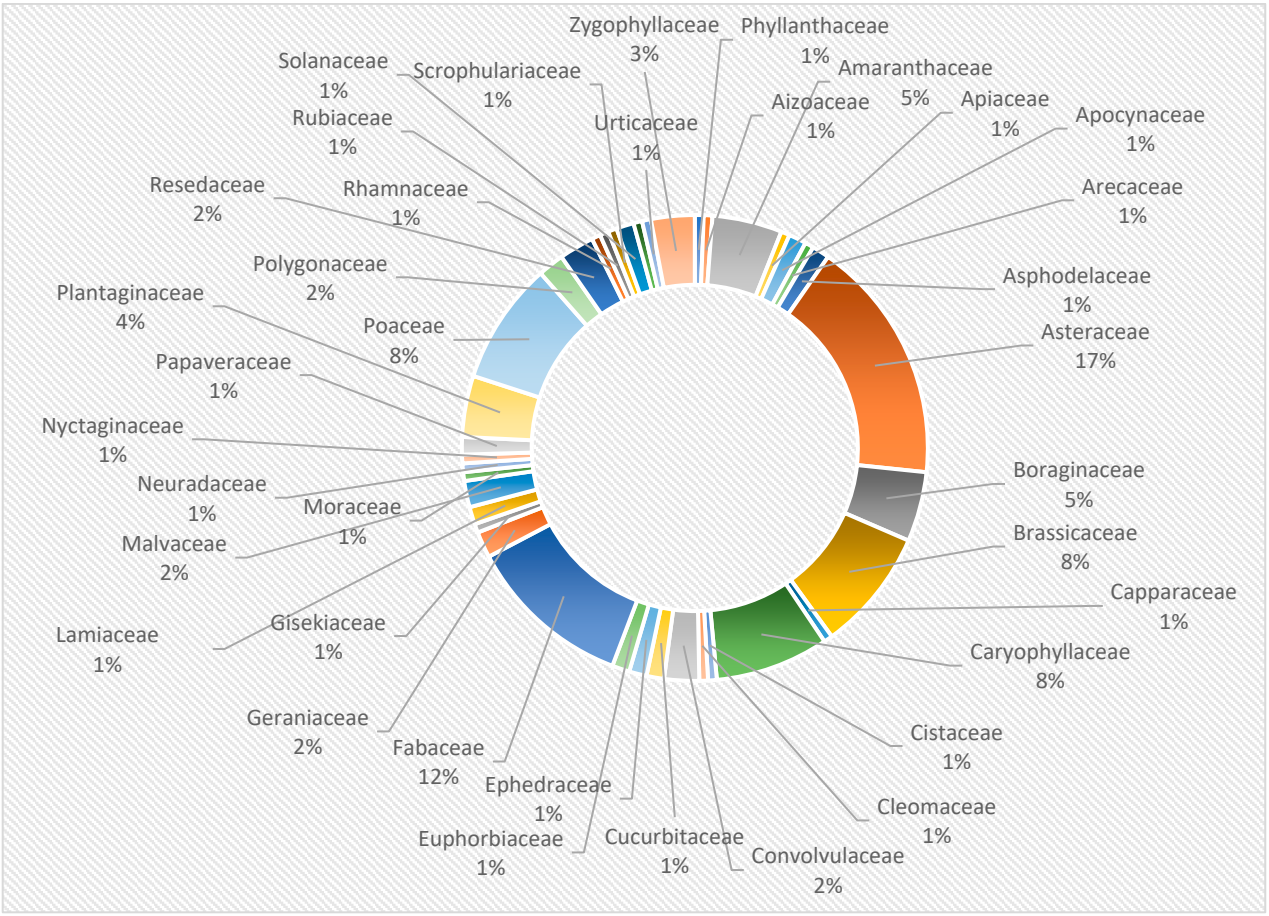

Figure 4. Distribution of taxa by botanical families.

4. Bioforms

The analysis of the biological types of the SNR flora allowed us to identify eight bioforms, of which the most dominant are the annual Therophytes (98 taxa, 57%), Chamaephytes (38 taxa, 22%), Phanerophytes (14 taxa, 8%), and Hemicryptophytes (12 taxa, 7%). The other biological types are poorly represented, such as Geophytes (4 taxa, 2%) and Cryptophytes (1 taxa, less than 1%). We also recognized some secondary forms, namely the Climbers (7 taxa, 4%) and the Parasites (1 taxa, less than 1%) (Figure 5).

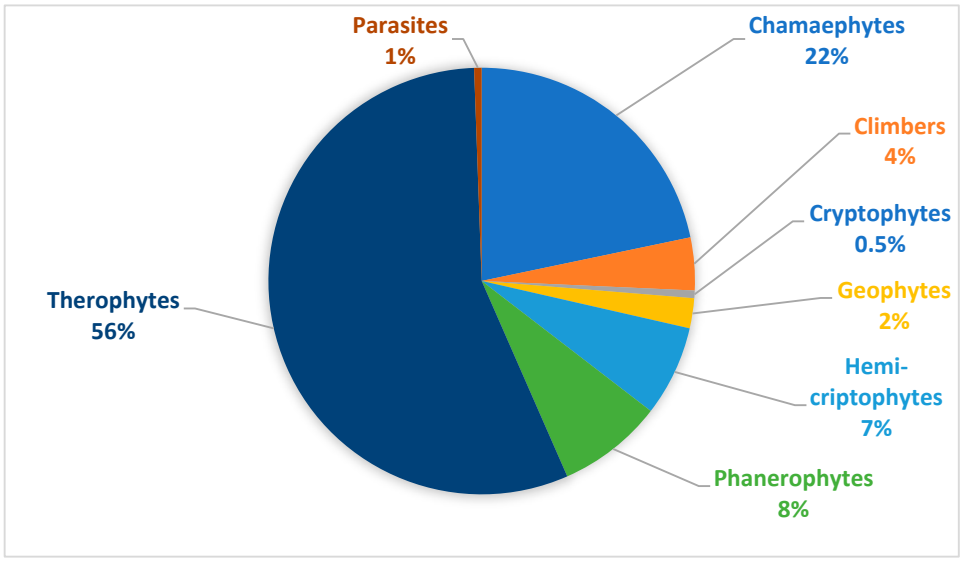

Figure 5. The bioforms spectrum.

5. Chorology of Taxa

The analysis of the chorology of the taxa led to the identification of 14 chorological types characterizing the flora of SNR. It turns out that this flora is mainly of Saharo-Arabian origin (116 taxa, 50%). The other existing chorological types are composed of the Irano-Turanian (34 taxa, 15%), Sudanian (33 taxa, 14%), as well as the Mediterranean element (21 taxa, 9%). The rest of the chorotypes are poorly represented, with a number of taxa lower than 10 and percentages lower than 5% (Figure 6).

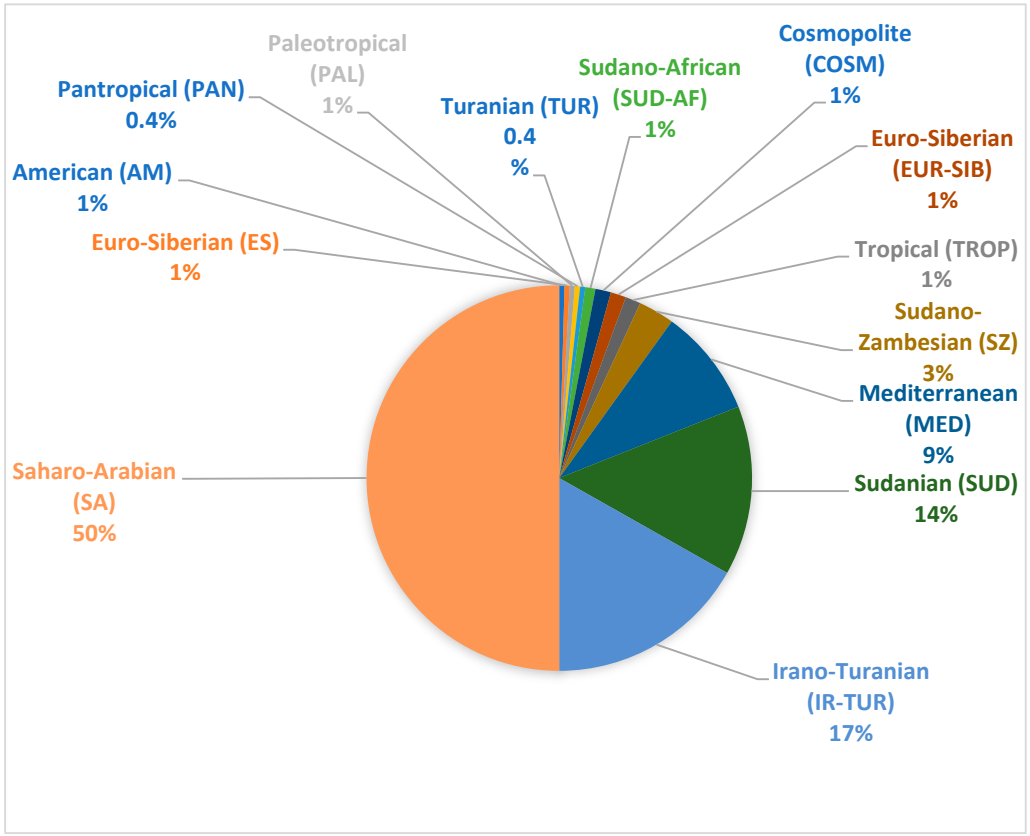

Figure 6. The floristic elements spectrum.

6. Biogeography of the SNR Flora (Comparative Study)

The biogeographic analysis of the SNR flora using the available literature data at the national scale made it possible to recognize the most similar phytogeographic region to SNR in terms of floristic composition but also to recognize the plant taxa characterizing SNR compared to other previously studied areas in the KSA. The results of the NMS analysis revealed a floristic similarity with the northern closest phytogeographic zones to the AlUla region, namely the regions of Tabuk and Hail located in the following phytogeographic sectors: North Hejaz (NH), Northern region (N), and Nefud (NF) (Figure 7).

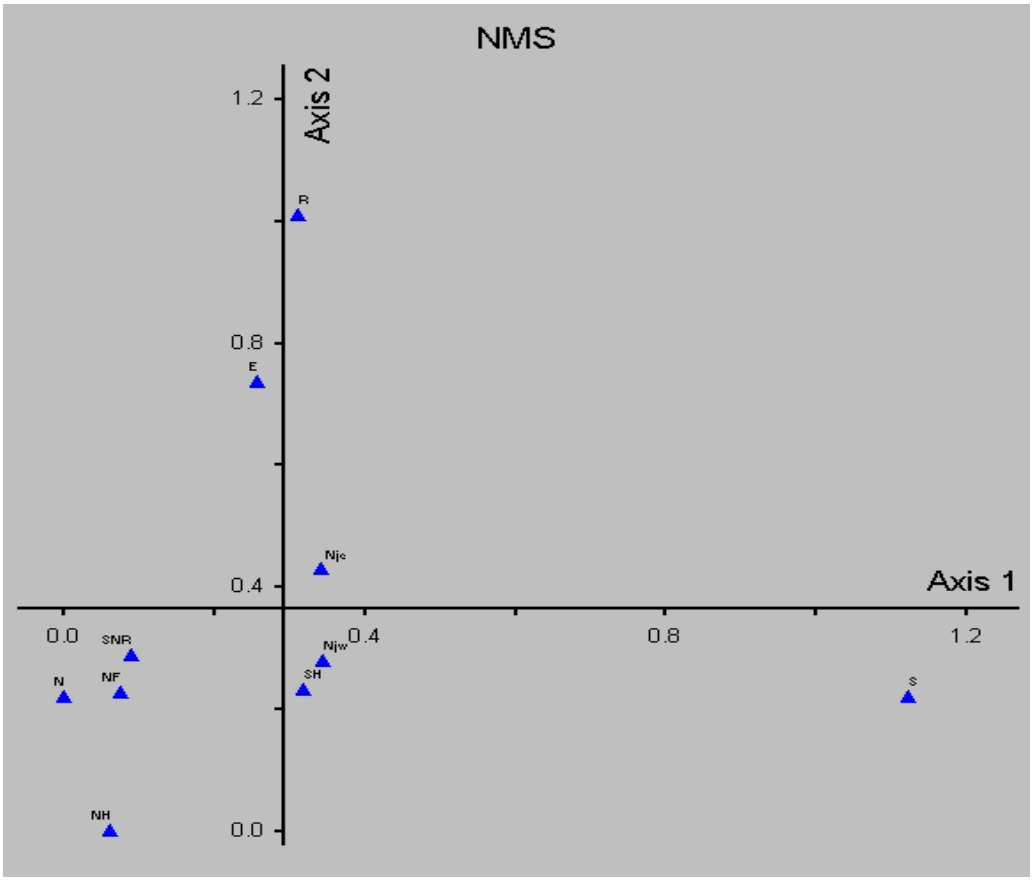

Figure 7. Non-Metric Multidimensional Scaling (NMS) showing floristic similarity between SNR and studies conducted across the KSA grouped by phytogeographic region.

The numerical analysis using the Venn diagram (Figure 8) confirms the results of the NMS by revealing that among the 166 taxa encountered in SNR, 126 are present in the region of Nefud (Hail), 125 in the Northern region and 107 in North Hejaz (mainly Tabuk region). The Najd region (including the western and eastern parts) contains a total of 137 species in common with SNR, while the southern Hijaz, Eastern region, and Al-Rubi Al-khale contain 96, 71, and 51 taxa, respectively. Finally, the southern region sector contains only 19 taxa of those encountered in SNR.

The comparative analysis of the SNR flora also showed the presence of 13 taxa of plants not existing in the consulted inventories, which are *Centropodia forskaolii* (Vahl) Cope, *Cuprella homalocarpa* (Fisch. & C.A.Mey.) Salmerón-Sánchez, Mota & Fuertes, *Euphorbia dracunculoides* Lam., *Hypecoum aegyptiacum* (Forssk.) Asch. & Schweinf., *Lappula spinocarpos* subsp. *ceratophora* (Popov) Y.J.Nasir, *Leptaleum filifolium* DC., *Minuartia hamata* Mattf., *Pallenis hierochuntica* (Michon) Greuter, *Plantago maris-mortui* Eig, *Senecio breviflorus* (Kadereit) Greuter, *Spergularia flaccida* (Madden) I.M.Turner, *Spergularia rubra* (L.) J.Presl & C.Presl and *Zygophyllum paulayanum* (J.Wagner & Vierh.) Christenh. & Byng.

These taxa, even those that do not appear in the regional inventories consulted, are not necessarily exclusive to the study area but may constitute characteristic taxa of SNR, thus reflecting a possible floristic originality of the reserve and AlUla area in general.

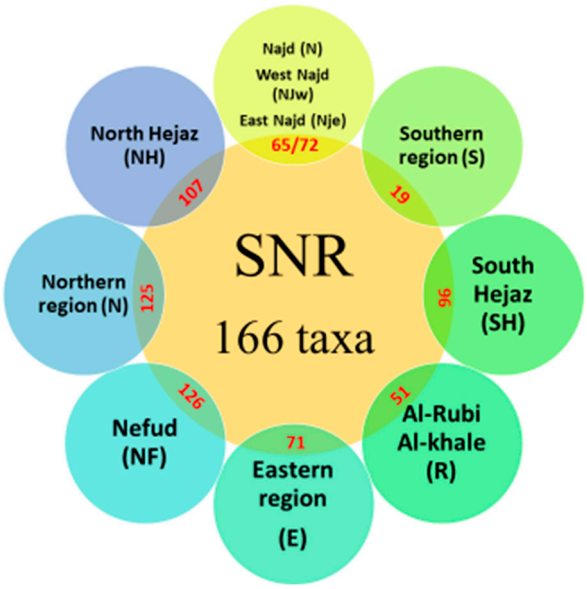

Figure 8. Venn diagram showing the number of species in common between SNR and consulted inventories grouped by phytogeographic regions.

7. Threatened Taxa

7.1. National Threatened

According to the list of threatened taxa of the KSA, it turns out that five taxa present in SNR are among the national threatened taxa in the KSA and meet different criteria, namely: *Calligonum comosum* L'Hér. (criterion: 1, 5, 6 and 7) found in dunes, *Ficus palmata* Forssk. (criterion 6) found in Vegetated red sandstone foot cliffs, *Haloxylon persicum* Bunge (criterion 5, 6) found in species-rich open shrubland formations and sandy open environments, *Phoenix dactylifera* L. (criterion 5, 6 and 7) found in Vegetated red sandstone foot cliff and *Vachellia gerrardi* (Benth.) P.J.H.Hurter (criterion 5) found in species-rich open shrubland formation (See Supplementary Table S1). According to the International Finance Corporation standards (IFC, PS6), *Calligonum comosum* L'Hér. appears in the list of high-priority taxa in the KSA as Critically Endangered, Endangered, or Vulnerable.

7.2. Global Threatened

According to the IUCN Red List (2024), 12 taxa present in several natural habitats in SNR have a Least Concern (LC) status, with a stable population in general, which are *Astragalus crenatus* Schult (Stable) and *Astragalus tribuloides* Delile (Stable), with both found in a sandy open environment, *Capparis decidua* (Forssk.) Edgew. (Stable), *Desmostachya bipinnata* (L.) Stapf (Unknown), *Ephedra alata* Decne. (Stable), *Ephedra ciliata* Fisch. & C.A.Mey. (Stable), *Haloxylon persicum* Bunge (Unknown), *Lycium shawii* Roem. & Schult. (Unknown), *Ochradenus baccatus* Delile (Unknown), *Tribulus terrestris* L. (Stable), and *Ziziphus nummularia* (Burm.f.) Wight & Arn. (Unknown) found all in the species-rich open shrubland formation and the sandy open environment and *Ficus palmata* Forssk. (Unknown).

8. Discussion

8.1. Taxonomic Diversity of the SNR Flora Despite the Arid Environment

The inventory of the SNR flora, so far, is not exhaustive because it did not systematically sample the entire reserve, but it remains quite representative of this area as it covers all the natural habitats existing in the reserve. The number of 166 plant taxa identified at SNR can be considered important compared to similar studies published across the KSA. Indeed, several published works in different regions report lower numbers of taxa, such as those of Obaid and Abdel-Hameed [14] in Al Madinah (33 taxa), Mohammed–Ibtisam and Doka [48] in Hafer Albatin (83 taxa), Aljedaani and Fakhry [49] in Jeddah (107 taxa), Alzamel [50] in Wadi AlFurayshah (26 taxa), Anazi et al. [51] in wadi Al-Akhthar-Tabuk region (82 taxa), Al-Mutairi et al. [52] in Tabuk province (96 taxa), Al-Namazi et al. [18] in Jandaf Mountain (118 taxa), Al Wadie [53] in Wadi Ayaa (53 taxa), Abdein and Osman [12] in Wadi Al-Hilali (116 taxa), Alsalem et al. [54] in Wadi Othylan (78 taxa), Osman et al. [55] in Wadi Muur Al-Zahran (118 taxa) and Moawed and Ansari [56] in Red Sea coastal region of Tabuk (82 taxa). Other inventories reported a higher number of taxa, such as Ansari et al. [17] in Tabuk (198 taxa), ElKordy et al. [57] in Jabal Al-Ward, Southwest Tabuk (198 taxa), Mandaville [33] in the Eastern KSA (565 taxa), Al-Eisawi and Al Ruzayza [58] in Mecca (184 taxa) and Al Masoudi [20] in Mecca (253 taxa). In the Al Baha region, several authors [16,59–61] proposed inventories with fairly large numbers of species (202, 190, 187, and 319 taxa, respectively).

Regarding the number of botanical families, with the exception of the studies of Ansari et al. [17] and ElKordy et al. [57] in Tabuk, Mandaville [33] in the Eastern KSA, Ghazal [16], Al-Kalby et al. [59], Al-Zandi et al. [60], and Al-Namazi et al. [61] in the Al Baha region, reporting numbers of families higher than those of our studies, all the other consulted papers rather report numbers of families quite similar to that of SNR.

Regarding the dominant families in our study (Asteraceae, Fabaceae, Brassicaceae), it turns out that several works published in the KSA observed more or less the same order and proportions found in the present study [5,12,20,48,51,56–58,62,63].

Other inventories [14,52,60] reported the presence of other botanical families among the most dominant ones, such as Zygophyllaceae and Lamiaceae, while the study of Gamal et al. [62] in Al Quassim investigated the weed plants of the region reported similar proportions to our study. The Asteraceae family has been highlighted by Collenette [11] as the one containing the largest number of plant species in Saudi Arabia. This is also the case in Yemen, where Wood [64] and Al-Khulaidi [65] reported that Asteraceae represent the most important botanical family in Yemen's flora. Similar findings were observed in several published works in Egypt [66,67].

8.2. Bioforms Reflecting Ecological and Geographical Conditions

Regarding the bioforms of taxa, the recorded proportions in the present study, especially the dominance of the two forms (Therophytes and Chamaephytes), are in agreement with the general spectrum found in desert habitats in Saudi Arabia [8,10,11,68–71]. In fact, the vegetation of the country, mainly xerophytic, is often dominated by the taxa of Therophytes and Chamaephytes [3]. According to Al-Taisan [72], this situation could be related to drought, topographic variations, high temperature, and soil salinity. The dominance of Therophytes in the regional published inventories in the KSA was observed by Sher and Al-Yemeni [73] in Al-Kharj, Alatar et al. [5] in Najd, Seraj et al. [63] in Asir, Al-Mutairi et al. [52] in Tabuk and Abdein and Osman [12] in Wadi Al-Hilali. According to Mobayen [74] in Al-Mutairi et al. [52]. The dominance of this biological type in the northern region of the KSA could be related to the prevalence of the Mediterranean climate. However, SNR, located in AlUla County, does not have a dominant Mediterranean climate

despite the influence that can be observed through the number of Mediterranean species present in the inventory (21 taxa). This is indeed an influence of the Mediterranean climate, which is due to the geographical position of the AlUla region, which is located not far from the areas with Mediterranean influence, i.e., the Tabuk region.

Otherwise, the dominance of Chamaephytes has been noted by Obaid and Abdel-Hameed [14] in Al Madinah, Al Masoudi [20] in Mecca, and by Anazi et al. [51], and Moawed and Ansari [56] in Tabuk region. This high occurrence of Chamaephytes could be associated with the local abiotic (desert climate, topography) and biotic factors [75–77].

8.3. Sharaan National Reserve: An Area of Floristic Transition?

In general, it has been proven that transitional areas of vegetation can constitute biodiversity hotspots as the species in these areas show a strong adaptation to climate change, making them crucial areas for long-term conservation [78]. The main indicator of this biogeographic situation would be chorology, which allows us to appreciate the phytogeographic affinities of the flora of a given area [79]. The dominance of the Saharo-Arabian mono-regional element in floristic inventories in the KSA is often observed in various nearby regions such as Al Madinah [14], Najd [5], and Tabuk [51,52,56,57].

In Saudi Arabia, the Saharo-Arabian element has been observed to extend further south but decrease towards the north, as its presence rather indicates arid conditions [80,81]. Otherwise, the dominance of this element may indicate a certain degree of protection and/or habitats with favorable microclimates [41,71,82,83], as is the case for the SNR reserve. Mandaville [33] highlighted that transitional regions contain relatively low proportions of endemics, which is the case in our study area.

The other elements (Irano-Turanian, Sudanian) are also present with significant proportions, which has already been observed in the Tabuk region by Al-Mutairi et al. [52]. The Irano-Turanian element is one of the most abundant chorotypes in the world, and it makes significant contributions to halophytic and xerophytic species [84,85]. According to Nadaf et al. [86], this element is dominant in North Khorasan Province, Iran, while the Sudanian element was observed to be dominant in some southern zones in Saudi Arabia, such as the Al Saoda region [63].

The presence of the Mediterranean element with 21 taxa in the region confirms geographical and floristic affinities and the influence of the Mediterranean on the northern part of the KSA. This was also observed several times in Tabuk areas by several authors, such as Al-Mutairi et al. [52]. According to Sulayem and Joubert [87], more than 1000 of the approximately 3500 plant species of the KSA have Mediterranean or Iranian affinities. The Mediterranean elements are mainly represented in the high-altitude areas, especially the mountains of the western escarpment, while the Iranian-Turanian elements penetrate into the eastern parts of the peninsula. The presence of these species indicates more or less moderate humidity conditions characterizing the Mediterranean climate [88,89]. Hence, this could confirm that SNR constitutes a transitional zone between the Saharo-Sindian region dominating KSA and the Northern zone with Mediterranean influence [41], where the Saharo-Arabian chorotype decreased northward and replaced by Mediterranean and Irano-Turanian [90,91].

The NMS results of the biogeographic comparative analysis reported floristic similarity with the surrounding areas, especially the Northern KSA (Tabuk and Hail) to which SNR and the AlUla region phytogeographically belong [44]. In contrast, the dominance of the Saharo-Arabian flora in the inventory suggests that our study area should belong to the Najd region, representing the central part of the KSA. This situation, which has been observed in certain transitional biogeographic regions [42], could be again justified by the geographical situation of the study area located between the center and the North

of the KSA. Thus, the SNR flora appears to group a mixture of diverse taxa consisting mainly of Saharo-Arabian with an introgression of several Irano-Turanian, Sudanian, and Mediterranean taxa indicating the contribution of taxa from different influences, in particular the northern and Mediterranean, but also the Sudanian zone in the west [22].

Therefore, this situation suggests that the AlUla region, despite its arid climate and desert landscape, constitutes a phytogeographic transition area characterizing the passage from the desert to more humid ecosystems towards the north. This can finally be observed and confirmed through the 16 taxa "exclusive" to the study area (compared to the consulted literature), which present a mixture of Saharo-Arabian plants such as *Hypecoum aegyptiacum* (Forssk.), *Pallenis hierichuntica* Michon) Greuter, *Plantago maris-mortui* Eig, *Senecio breviflorus* (Kadereit) Greuter, *Spergularia flaccida* (Madden) I.M.Turner and *Zygophyllum paulayanum* (J.Wagner & Vierh.) Christenh. & Byng, as well as Irano-Turanian taxa such as *Cuprella homalocarpa* (Fisch. & C.A.Mey.) Salmerón-Sánchez, Mota & Fuertes, *Leptaleum filifolium* DC., *Senecio glaucus* subsp. *coronopifolius* (Maire) C.Alexander. and Mediterraneans such as *Spergularia rubra* (L.) J.Presl & C.Presl and *Minuartia hamata* Mattf.

8.4. A Preserved Diverse Flora in SNR

Beyond the floristic diversity observed in the SNR, of which this inventory constitutes a sample to be completed later by more extensive investigations, the flora of the reserve reveals several biogeographic information, especially a significant number of Irano-Turanian and Mediterranean taxa confirming that it is a floristic transition area in the KSA.

From a conservation point of view, the good news is that the SNR flora has been protected by a closure, allowing only limited and monitored access to the reserve since 2020. Knowing that the reserve contains a number of 13 taxa reported in the IUCN red list [45] as of Least Concern, these taxa, and despite their generally non-worrying status, with population trends often stable or not assessed, constitute an important element in the process of assessing the health of natural habitats and ecological monitoring of ecosystems [92]. In addition, we note the presence of a species assessed as threatened at the national scale (*Calligonum comosum* L'Hér.), meeting a PS6 criterion [47]. According to AbuZinada et al. [46], this species meets the threshold (c) of Criterion 1 of the PS6 (As appropriate, areas containing important concentrations of a nationally or regionally (listed EN or CR species). This makes it possible to classify the habitat of this species as "*Critical habitats*". Critical habitat is defined in Paragraph 16 of the 2012 version of IFC Performance Standard 6 (IFC PS6) as an area with high biodiversity value [47].

9. Conclusions

Floristic transition zones are geographical areas that contain rich and diverse flora due to their diversity in natural habitats and ecological contrast.

Better knowledge of the flora of unexplored areas in the KSA, particularly protected areas, should constitute a priority to better protect and conserve the biodiversity and natural habitats in these areas.

Our study reports a first floristic inventory of the Sharaan Nature Reserve with 166 taxa of plants belonging to 38 botanical families. This is mainly a therophytic flora dominated by the Saharo-Arabian element with a remarkable presence of the Mediterranean and Irano-Turanian species, suggesting a situation of floristic transition. The comparative phytogeographical analysis of the reserve's flora confirms this situation, while a certain number of exclusive, locally and globally threatened taxa are identified in the reserve.

It appears that the Sharaan Natural Reserve constitutes a phytogeographic and floristic transition area that allows it to shelter a taxonomically and chorologically diverse flora. The

protection of these taxa should also concern their natural habitats like *Calligonum comosum* L'Hér. growing in the dunes.

Supplementary Materials: The following supporting information can be downloaded at https://www.mdpi.com/article/10.3390/d17010030/s1, Supplementary Table S1: All studied plant species inventory.

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References

1. Alzamel, N.M. Vegetation Structure and Floristic Features of Al Rayn Region, Saudi Arabia. *Adv. Environ. Stud.* **2015**, *5*, 436–442.
2. AtiqurRahman, M.; Mossa, J.S.; Al-Said, M.S.; AlYahya, M.A. Medicinal plant diversity in the flora of Saudi Arabia. 1: A report on seven plant families. *Fitoterapia* **2004**, *75*, 149–161.
3. Khalik, K.A.; El-sheikh, M.; El-Aidarous, A. Floristic diversity and vegetation analysis of Wadi Al-Noman, Mecca, Saudi Arabia. *Turk. J. Bot.* **2013**, *37*, 894–907. [CrossRef]
4. Shaltout, K.H.; El-Sheikh, M.A. Vegetation of the urban habitats in the Nile Delta region, Egypt. *Urban Ecosyst.* **2003**, *6*, 205–221. [CrossRef]
5. Shaltout, K.-H.; Mady, M.-A. Analysis of raudhas vegetation in central Saudi Arabia. *J. Arid. Environ.* **1996**, *34*, 441–454. [CrossRef]
6. Migahid, A.M. *Flora of Saudi Arabia*, 2nd ed.; Riyadh University Publication: Riyadh, Saudi Arabia, 1978; Volume I.
7. Chaudhary, S.A. *Flora of the Kingdom of Saudi Arabia*; Ministry of Agriculture and Water: Riyadh, Saudi Arabia, 1999; Volume I.
8. Chaudhary, S. *Flora the Kingdom of Saudi Arabia Illustrated*; National Herbarium Ministry of Agriculture and Water Kingdom of Saudi Arabia: Riyadh, Saudi Arabia, 2001; Volume 2, pp. 1–542.
9. Chaudhary, S.; Al-Jowaid, A. *Vegetation of the Kingdom of Saudi Arabia*; National Agriculture and Water Research Center Ministry of Agriculture and Water Kingdom of Saudi Arabia: Riyadh, Saudi Arabia, 2013; Volume 1, pp. 1–680.
10. Collenette, S. *An Illustrated Guide to the Flowers of Saudi Arabia*; Scorpion Publishing Ltd.: London, UK, 1985.
11. Collenette, S. *Wild Flowers of Saudi Arabia*; National Commission for Wild Life Conservation and Development (NCWCD) & Sheila Collenette, King Fahd National Library, Kingdom of Saudi Arabia: Riyadh, Saudi Arabia, 1999; 799p.
12. Abdein, M.A.; Osman, A.K.E. Plant Diversity Assessment of Wadi Al-Hilali, Northern Border Region, Saudi Arabia. *Int. J. Bot. Stud.* **2020**, *5*, 87–95.
13. Qari, S.H.; Alrefaei, A.F.; Filfilan, W.; Qumsani, A. Exploration of the Medicinal Flora of the Aljumum Region in Saudi Arabia. *Appl. Sci.* **2021**, *11*, 7620. [CrossRef]
14. Obaid, W.A.; Hameed, U.K.A. Angiospermic flora of Wadi Al Aqiq in Al-Madinah Al-Munawarah, Saudi Arabia. *Bangladesh J. Plant Taxon.* **2021**, *28*, 271–276. [CrossRef]
15. Fadl, M.A.; Al-Yasi, H.M.; Alsherif, E.A. Impact of Elevation and Slope Aspect on Floristic Composition in Wadi Elkor, Sarawat Al-Eisawi, Mountain, Saudi Arabia. *Sci. Rep.* **2021**, *11*, 16160. [CrossRef]
16. Ghazal, A.M.F. Assessment of potential functional use of floristic compositions in landscape restoration of habitats in arid regions. *Pak. J. Bot.* **2021**, *53*, 2143–2155. [CrossRef]
17. Ansari, A.A.; Siddiqui, Z.H.; Alatawi, F.A.; Alharbi, B.M.; Alotaibi, A.S. An Assessment of Biodiversity in Tabuk Region of Saudi Arabia: A Comprehensive Review. *Sustainability* **2022**, *14*, 10564. [CrossRef]

18. Al-Namazi, A.A.; Algarni, S.M.; Wan, J.S.; Al Mosallam, M.S.; Alotaibi, F. Floristic composition of Jandaf Mountain as biodiversity hotspot area in southwestern Saudi Arabia. *Saudi J. Biol. Sci.* **2022**, *29*, 3654–3660. [CrossRef]
19. Al-Qahtani, S.M.; El-Hashash, E.F.; El-Absy, K.M.; Al-Taymanl, A.M.; Al-Zwain, G.Z.; Al-Faqeer, M.N.; Al-Fahiqi, M.A.; Alatawi, Z.D.; Alfuhigi, A.Z.M.; Al-Fahiqi, R.K.M.H. Diversity of weeds species in grapes farms of Tayma (Tabuk, Saudi Arabia): Implication for invasive species ecology. *Biosci. J.* **2023**, *39*, e39088. [CrossRef]
20. Al Masoudi, L. Plant Diversity in Some Habitats in Saudi Arabia with Its Economic Uses. *Sohag J. Sci.* **2024**, *9*, 439–442. [CrossRef]
21. Thomas, J.; Sivadasan, M.; Al-Ansari, A.M.; Alfarhan, A.; El-Sheikh, M.; Basahi, M.; Alatar, A.A. New generic and species records for the flora of Saudi Arabia. *Saudi J. Biol. Sci.* **2014**, *21*, 457–464. [CrossRef]
22. Al-Nafie, A.H. Phytogeography of Saudi Arabia. *Saudi J. Biol. Sci.* **2008**, *15*, 159–176.
23. Al-Rehaily, A.; Thomas, J.; Yusuf, M.; Mayandy, S.; Alfarhan, A.H.; El-Sheikh, M.A.; Alatar, A. Taxonomy and distribution of two newly recorded genera in Saudi Arabia. *Kuwait J. Sci.* **2015**, *42*, 158–169.
24. Al-Sodany, A. New Record to the Flora of Saudi Arabia: *Ipomoea carnea* Jacq. Convolvulaceae. *World J. Res. Rev.* **2016**, *3*, 25–30.
25. Basahi, M.A.; Masrahi, Y.S. Blepharis saudensis (Acanthaceae), a new species from Saudi Arabia. *Saudi J. Biol. Sci.* **2019**, *26*, 1509–1512. [CrossRef] [PubMed]
26. Al-Khulaidi, A.W.; Al Faify, E.A.; Alfaifi, M.M.; Al-Namazi, A.A.; Al-Khulaidi, F.; Filimban, M.; Alfaifi, A.; Al-Namazi, A. A New Record of Generic Vascular Plant for the Flora of Saudi Arabia: *Aspilia kotschyi* (Asteraceae). *Saudi J. Biol. Sci.* **2021**, *28*, 1962–1965. [CrossRef]
27. Al-Khulaidi, A.W.; Al-Sagheer, N.; Filimban, F.Z. *Erigeron canadensis* L. (Asteraceae): A New Record to the Flora of the Arabian Peninsula. *J. North Basic Appl. Sci.* **2021**, *6*, 30–46.
28. Al-Robai, S.A.; Ali Ahmed, A.; Mohamed, H.A.; Alzahrani, F.O. *Austrocylindropuntia subulata* (Muehlenpf.) Backeb. (Cactaceae, Opuntioideae): An invasive new cactus record to the flora of Saudi Arabia. *BioInvasions Rec.* **2022**, *11*, 360–366. [CrossRef]
29. Al-Khulaidi, A.W.; Al-Faify, E.A.; Alfaifi, M.M.; Al-Namazi, A.A. New records and addition to the flora of Saudi Arabia, mainly from Faifa Governorate, Jazan Region. *J. King Saud Univ.* **2023**, *35*, 102424. [CrossRef]
30. Al-Khulaidi, A.W.; Alzahrani, A.M.; Al-Namazi, A.A.; Al-Faify, E.A.; Alfaifi, M.M.; Al-Sagheer, N.A.; Al-Gifri, A.N. New plant records for the flora of Saudi Arabia. *J. Threat. TAXA* **2024**, *16*, 24899–24909. [CrossRef]
31. Wilson, J.W.; Primack, R.B. *Conservation Biology in Sub-Saharan Africa*; Open Book Publishers: Cambridge, UK, 2019. [CrossRef]
32. Al-Saadon, K.H.; Saudi Wildlife Authority. Action Plan for Implementing the Convention on Biological Diversity's Programme of Work on Protected Areas. Riyadh, Saudi Arabia. 2012. Available online: https://www.cbd.int/doc/world/sa/sa-nbsap-powpa-en.pdf (accessed on 29 September 2024).
33. Mandaville, J.P. *Flora of Eastern Saudi Arabia*; Kegan Paul International, London & N.Y. Jointly with the National Commission for Wildlife Conservation and Development: Riyadh, Saudi Arabia, 1990; pp. 130–155.
34. Smith, T.B.; Kark, S.; Schneider, C.J.; Wayne, R.K.; Moritz, C. Biodiversity hotspots and beyond: The need for conserving environmental transitions. *Trends. Ecol. Evol.* **2001**, *16*, 431. [CrossRef]
35. Morandi, P.S.; Marimon, B.S.; MarimonJunior, B.H.; Ratter, J.A.; Feldpausch, T.R.; Colli, G.R.; Munhoz, C.B.; Silva-Júnior, M.C.; Souza-Lima, E.; Haidar, L.R.F.; et al. Tree diversity and above-ground biomass in the South America Cerrado biome and their conservation implications. *Biodivers. Conserv.* **2020**, *29*, 1519–1536. [CrossRef]
36. Pavoine, S.; Vela, E.; Gachet, S.; de Bélair, G.; Bonsall, M.B. Linking patterns in phylogeny, traits, abiotic variables and space: A novel approach to linking environmental filtering and plant community assembly. *J. Ecol.* **2011**, *99*, 165–175. [CrossRef]
37. Kent, M. *Vegetation Description and Data Analysis: A Practical Approach*; John Wiley & Sons: Hoboken, NJ, USA, 2011.
38. Boulos, L. *Flora of Egypt*; Checklist; Al Hadara Publishing: Cairo, Egypt, 2009; 410p.
39. Zohary, M.; Feinbrun-Dothan, N. *Flora Palaestina*; Academy of Sciences and Humanities: Jerusalem, Israel, 1966.
40. Zohary, M. *Flora Palaestina: Platanaceae to Umbelliferae*; Israel Academy of Sciences and Humanities: Jerusalem, Israel, 1972; Volume 2, p. 489.
41. Zohary, M. *Geobotanical Foundations of the Middle East*; Gustav Fischer: Stuttgart, Germany, 1973.
42. White, F.; Léonard, J. Phytogeographical links between Africa and southwest Asia. *Flora Veg. Mundi* **1991**, *9*, 229–246.
43. Migahid, A.M. *Flora of Saudi Arabia*; King Saud University Press: Riyadh, Saudi Arabia, 1996.
44. Migahid, A.M.; Hammouda, M.A. *Flora of Saudi Arabia*; Riyad University: Riyadh, Saudi Arabia, 1974; 574p.
45. IUCN. International Union for Conservation of Nature and Natural Resources. 2024. Available online: https://www.iucnredlist.org/ (accessed on 1 October 2024).
46. AbuZinada, A.H.; Robinson, E.R.; Nader, I.A.; Al Wetaid, Y.I. *First Saudi Arabian National Report on the Convention on Biological Diversity*; The National Commission for Wildlife Conservation and Development: Riyadh, Saudi Arabia, 2004; Available online: https://www.cbd.int/doc/world/sa/sa-nr-01-en.pdf (accessed on 9 October 2024).
47. IFC. *Performance Standard 6: Biodiversity Conservation and Sustainable Management of Living Natural Resources*; International Finance Corporation (IFC): Washington, DC, USA, 2012.

48. Mohammed-Ibtisam, M.I.; Doka, G.M. Check list of flora and vegetation of Hafer Albatin region, northeastern Saudi Arabia. *MOJ Ecol. Environ. Sci.* **2018**, *3*, 138–143. [CrossRef]
49. Aljedaani, G.; Fakhry, A. Floristic Diversity of Jeddah: An Arid Desert, Western Region of Saudi Arabia. *Egypt. J. Bot.* **2023**, *63*, 57–68. [CrossRef]
50. Alzamel, N. Floristic composition and vegetation analysis in Wadi AlFurayshah region, Saudi Arabia. *J. Environ. Stud.* **2022**, *28*, 35–40. [CrossRef]
51. Anazi, H.; Bukhari, N.; Al-Farhan, A. Floristic diversity of Al wadi Al-Akhthar, Tabuk region, Saudi Arabia. *Int. J. Bot. Stud.* **2022**, *7*, 29–34.
52. Al-Mutairi, K.A.; Al-Shami, S.A.; Khorshid, Z.B.; Moawed, M.M. Floristic diversity of Tabuk province, North Saudi Arabia. *JAPS J. Anim. Plant Sci.* **2016**, *26*, 1019–1025.
53. Al Wadie, H.M. Plant communities in Wadi Ayaa southwestern Saudi Arabia. *Egypt. J. Exp. Biol.* **2007**, *3*, 1–8.
54. Alsalem, A.A.; Alfarhan, A.A.; El-Sheikh, M.A. Floristic structure and vegetation diversity of the wadi Othylan protected area in Saudi Arabia. *App. Ecol. Environ. Res.* **2020**, *18*, 8119–8130. [CrossRef]
55. Osman, H.E.; Soliman, M.A.; El-Morsy, M.H.; Elaidarous, A.A.; Galal, T.M. Plant diversity and community composition along the prevailing environmental conditions in Wadi Murr Al-Zahran, southwestern Saudi Arabia. *App. Ecol. Environ. Res.* **2024**, *22*, 2999–3020. [CrossRef]
56. Moawed, M.M.; Ansari, A.A. Wild plants diversity of Red Sea coastal region, Tabuk, Saudi Arabia. *J. Chem. Pharm. Res.* **2015**, *7*, 220–227.
57. Elkordy, A.; Nour, I.H.; Ellmouni, F.Y.; Al Shaye, N.A.; Al-Bakre, D.A.; EL-Banhawy, A. Floristic Diversity of Jabal Al-Ward, Southwest Tabuk Region, Kingdom of Saudi Arabia. *Agronomy* **2022**, *12*, 2626. [CrossRef]
58. Al-Eisawi, D.M.; Al-Ruzayza, S. The flora of holy Mecca district, Saudi Arabia. *Int. J. Biodivers. Conserv.* **2015**, *7*, 173–189.
59. Al-kalby, A.; Al-Khulaidi, A.W.; Hussain, A.; Al-Sagheer, N. Main vegetation types and plant species diver sity along an altitud inal gradient of Al Baha region, Saudi Arabia. *Saudi J. Biol. Sci.* **2016**, *6*, 687–697. [CrossRef]
60. Al-Zandi, A.; Al-Khulaidi, A.W.; AL-Sagheer, N.A. Preliminary Analysing of plant Diversity of high altitude area of Albaha region, Saudi Arabia. *Int. J. Adv. Res.* **2018**, *6*, 412–426. [CrossRef] [PubMed]
61. Namazi, A.A.; Al-Khulaidi, A.W.; Algarni, S.; Al-Sagheer, N.A. Natural plant species inventory of hotspot areas in Arabian Peninsula: Southwest Al-Baha region, Saudi Arabia. *Saudi J. Biol. Sci.* **2021**, *28*, 3309–3324. [CrossRef]
62. Gamal, E.B.G.; Al-Soqeer, A.A. A checklist of the weed flora of Qassim Region, Saudi Arabia. *Aust. J. Basic Appl. Sci.* **2013**, *7*, 900–905.
63. Seraj, S.S.; Jrais, R.N.; Ayyad, S.K. Floristic Composition, Life Form and Chorology of Plant Life at Al-Saoda, Asir Region, South-Western Saudi Arabia. *J. Biol. Agric. Healthc.* **2014**, *4*, 60–65.
64. Wood, J.R.I. *A Handbook of the Yemen Flora*; Royal Botanic Gardens, Kew: Richmond, UK, 1997; p. 434.
65. Al-Khulaidi, A.W. *Flora of Yemen*; Natural Resource Management Project (SNRMP): Sanaa, Yemen, 2012; 266p.
66. El-Ghani, M.M.A.; El-Sawaf, N. Diversity and distribution of plant species in agro-ecosystems of Egypt. *Syst. Geogr. Plants* **2004**, *74*, 319–336.
67. El-Ghani, M.M.A.; Abdel-Khalik, K.N. Floristic diversity and phytogeography of the Gebel Elba National Park, south-east Egypt. *Turk. J. Bot.* **2006**, *30*, 121–136.
68. El-Demerdash, M.; Hegazy, A.; Zilay, A. Distribution of the plant communities in Tihamah coastal plains of Jazan region, Saudi Arabia. *Vegetatio* **1994**, *112*, 141–151. [CrossRef]
69. Al-Turki, T.A.; Al-Qlayan, H.A. Contribution to the flora of Saudi Arabia: Hail region. *Saudi J. Biol. Sci.* **2003**, *10*, 190–222.
70. Fahmy, A.G.; Hassan, L.M. Plant diversity of wadi el Ghayl, Aseer Mountains, Saudi Arabia. *Egypt. J. Desert Res.* **2005**, *55*, 39–52.
71. El-Ghanim, W.; Hassan, L.; Galal, T.; Badr, A. Floristic composition and vegetation analysis in Hail region north of central Saudi Arabia. *Saudi J. Biol. Sci.* **2010**, *17*, 119–128. [CrossRef]
72. Al-Taisan, W.A. Floristic diversity and vegetation of the az Zakhnuniyah Island, Arabian Gulf, Saudi Arabia. *Heliyon* **2022**, *8*, e09996. [CrossRef]
73. Sher, H.; Al-Yemeny, M.N. Ecological investigation of the weed flora in arable and non arable lands of Al-kharj Area, Saudi Arabia. *Int. J. Agric. Econ. Ext.* **2020**, *8*, 001–006.
74. Mobayen, S. *Flora of Iran*; Tehran University Press: Tehran, Iran, 1996; Volumes 1–4.
75. Zahran, M. *Vegetation Types of Saudi Arabia*; King Abdel Aziz University Press: Jeddah, Saudi Arabia, 1982.
76. Alshammari, A.M.; Sharawy, S.M. Wild plants diversity of the Hema Faid region (Ha'il Province, Saudi Arabia). *Asian J. Plant Sci.* **2004**, *9*, 447–454. [CrossRef]
77. Al-Yasi, H.M.; Alotaibi, S.S.; Al-Sodany, Y.M.; Galal, T.M. Plant distribution and diversity along altitudinal gradient of Sarrawat Mountains at Taif Province Saudi Arabia. *Biosci. Res.* **2019**, *16*, 1198–1213.

78. Zhou, R.; Ci, X.; Hu, J.; Zhang, X.; Cao, G.; Xiao, J.; Liu, Z.; Li, L.; Thornhill, A.H.; Conran, J.G.; et al. Transitional areas of vegetation as biodiversity hotspots evidenced by multifaceted biodiversity analysis of a dominant group in Chinese evergreen broad-leaved forests. *Ecol. Indic.* **2023**, *147*, 110001. [CrossRef]
79. Le Houérou, H.N. Biogeography of the arid steppeland north of the Sahara. *J. Arid Environ.* **2001**, *48*, 03–128. [CrossRef]
80. Elaidarous, A.A.; Osman, H.E.; Galal, T.M. Vegetation–environment relationship and floristic diversity of Wadi Al-Sharaea, Makkah Province, Saudi Arabia. *Rend. Fis. Acc. Lincei* **2022**, *33*, 169–184. [CrossRef]
81. Galal, T.M.; Al-Yasi, H.M.; Fadl, M.A. Vegetation zonation along thedesert-wetland ecosystem of Taif Highland, Saudi Arabia. *Saudi J. Biol. Sci.* **2021**, *28*, 3374–3383. [CrossRef] [PubMed]
82. Hegazy, A.K.; El-Demerdash, M.A.; Hosni, H.A. Vegetation, species diversity and floristic relations along an altitudinal gradient in South-West Saudi Arabia. *J. Arid Environ.* **1998**, *38*, 3–13. [CrossRef]
83. Ghazanfar, S.A.; Fisher, M. *Vegetation of the Arabian Peninsula*; Springer Science & Business Media: Berlin/Heidelberg, Germany, 2013; Volume 25.
84. Manafzadeh, S.; Staedler, Y.M.; Conti, E. Visions of the past and dreams of the future in the orient: The Irano-Turanian region from classical botany to evolutionary studies. *Biol. Rev.* **2017**, *92*, 1365–1388. [CrossRef] [PubMed]
85. Ramezani, E.; Talebi, T.; Alizadeh, K.; Shirvany, A.; Hamzeh'ee, B.; Behling, H. Long-Term Persistence of Steppe Vegetation in the Highlands of Arasbaran Protected Area, Northwestern Iran, as Inferred from a Pollen Record. *Palynology* **2021**, *45*, 15–26. [CrossRef]
86. Nadaf, M.; Mortazavi, M.; Halimi, M.K. Flora, Life forms and Chorotypes of Plants of Salok Protected Area (North Khorassan Province Iran). *Pak. J. Biol. Sci.* **2011**, *14*, 34–40. [CrossRef] [PubMed]
87. Sulayem, M.; Joubert, M. Management of Protected Areas in the Kingdom of Saudi Arabia. 2024. Available online: https://www.fao.org/4/v2900e/v2900e08.htm (accessed on 2 October 2024).
88. Hamed, Y.; Hadji, R.; Redhaounia, B. Climate impact on surface and groundwater in North Africa: A global synthesis of findings and recommendations. *Euro-Mediterr. J. Environ. Integr.* **2018**, *3*, 25. [CrossRef]
89. Alsherif, E.A. Ecological studies of *Commiphora* genus (myrrha) in Makkah region, Saudi Arabia. *Heliyon* **2019**, *5*, e01615. [CrossRef]
90. Hegazy, A.K.; Amer, W.M. Altitudinal and Latitudinal Diversity of the Flora on Eastern and Western Sides of the Red Sea. In *Biodiversity*; Şener, B., Ed.; Springer: Boston, MA, USA, 2002. [CrossRef]
91. Danin, A.; Plitman, U. Revision of the plant geographical territories of Israel and Sinai. *Plant Syst.* **1987**, *156*, 43–53. [CrossRef]
92. IUCN. *An Introduction to the IUCN Red List of Ecosystems: The Categories and Criteria for Assessing Risks to Ecosystems*; IUCN: Gland, Switzerland, 2016; vi+14p. [CrossRef]