Al-Hassa Oasis as a hotspot for plant diversity in Eastern Saudi Arabia

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Article

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Abstract

Biodiversity hotspots are geographic areas with an exceptionally high richness of species, including rare and endemic species. Such hotspots have deep evolutionary roots and are concentrated in areas where past climatic variability was moderate. The present study highlights of the plant diversity in Al-Hassa region to determine the importance of this area as a hottest hotspot and thus to pinpoint super priorities for conservation From spring 2020 to winter 2024, several field expeditions were conducted across multiple locations throughout Al-Hassa region to survey all identified habitat types. Supplementary information was obtained from comprehensive review of published literature encompassing journal articles, reference books, graduate theses, and technical reports. The total number of the recorded species in Al-Hassa Oasis was 282 species (12.5% of the total flora of KSA) belonging to 187 genera and 58 families. The family Poaceae has the highest contribution to the total flora, followed by Chenopodiaceae, Asteraceae, Brassicaceae and Fabaceae. The neglected palm orchards had the highest number of species (80 species), followed by water bodies (77 spp.), sand sheets (71 spp.) and cultivated palm orchards (66 spp.). The bi-regionals elements were the highest, followed by mono-regionals, while the pluri-regional including cosmopolitans were the lowest. Two endemic species (*Caroxylon arabicum* (Botsch.) Akhani & Roalson and *Zygophyllum mandavillei* Hadidi) and 5 near-endemic (*Halothamnus bottae* Jaub. Et Spach, *Horwoodia dicksoniae* Turrill, *Limeum arabicum* Friedrich, *Matthiola arabica* Boiss. and *Zygophyllum qatarense* Hadidi) were recorded. From the biodiversity viewpoint, the present study concludes that this area seems to be the richest area of the Kingdom taking into account its relatively small area comparing with the area of the whole country (it represents about 0.003% of the total area of Kingdom). This conclude that this area should be selected as a hotspot area for plant diversity in the Kingdom.

Introduction

Currently, species are lost by human actions at a rate 100–1000 times faster than they would naturally [1]. Frighteningly, at this rate it is estimated that up to 40% of the world's species might be lost by 2050 [2]. Even though these figures may be exaggerated, the truth remains that approximately 20,000 species are in risk of going extinct, and another 20,000 are currently classified as critically endangered, endangered, or vulnerable [3]. These numbers greatly outweigh the available biodiversity conservation resources. Additionally, species' locations and threats are not fairly distributed, with the most biodiverse areas frequently have the highest threats [4]. National efforts to conserve biodiversity must be complemented by a methodical approach to conservation planning that targets the most urgently needed places on a global scale. In order to prevent the extinction of species that are currently posing the greatest threat to our own existence, it is imperative that this be done [5]. Deforestation, plant cultivation and animal husbandry are only a few of the human activities that contribute to biodiversity loss [6]. These have a similar effect on seed plants and mosses. The identification of key sites for conservation is currently a major challenge as a result of this loss of biodiversity. Finding hotspots is one of these tasks that is important for biodiversity conservation [5].

Hotspots are areas comprising extraordinary concentrations of endemic species and experiencing exceptional habitat loss [7]. Today, the most striking feature, however, is that these hotspots of biodiversity, due to extensive habitat loss, only cover 2.3% of the Earth's land surface [8]. This means that more than half of our planet's natural heritage will be saved if the insignificantly small fraction of land were protected. The most common approach to identify hotspots is to locate areas with high taxonomic richness. Other approaches include endemism indices [9], panbiogeography [10, 11], phylogenetic diversity [12], and complementary analysis [13, 14]. Based on the existence of endemic plant and animal taxa, the biogeographic regionalization of the Earth has been practiced since the nineteenth century and is regularly updated. The evolutionary biogeographic techniques are important in identifying hotspots in addition to the criteria currently in use [10, 15]. Moreover, many studies have proposed biodiversity hotspots based on different criteria, taxa and geographic contexts [5, 8, 16, 17, 18, 19], and plant phylogenetic diversity [20].

One of the main characteristics of the vegetation cover of Saudi Arabia is its low floristic diversity. Al-Nafie [21] recorded 2172 species in the country, belonging to 840 genera and 149 families, many of which are in the wetter areas of its south-western part, while Collenette [22] recorded 2250 species belong to 835 genera and 142 families. Numbers of families, genera, and species are very low compared to Saudi Arabia's vast land area, which is probably, the result of the harsh environmental conditions that prevail in the Saharo-Arabian region which covers vast area of the country. The greatest plant diversity, approximately 74% of the total plant species of Saudi Arabia, is found in the mountainous western area due mainly to a greater rainfall [23].

Studies on the vegetation of central Saudi Arabia, particularly that of raudhas, are rare. Vesey-Fitzgerald [24] described briefly, among other vegetation types in the central and eastern region, the vegetation of Khuraim (one of the raudhas examined in the present study: 25° 20' N, 47° 15' E). Migahid et al. [25] briefly described the major habitats and their dominant species in the central and eastern region. Vesey-Fitzgerald [24], El-Sheikh and Youssef [26], and El-Sheikh et al. [27] studied the vegetation near springs, and that of gravel areas and salt marshes in the central region. Saltout and El-Halawany [28, 29] studied the weed communities of the date palm and vegetation of irrigation and drainage canals in the eastern Saudi Arabia. In addition, Shaltout and Madi [30, 31] studied the vegetation of some raudhas in central Saudi Arabia.

Al-Ahsa Oasis consists of gardens, canals, springs, wells, a drainage lake, as well as historic buildings, urban fabric and archaeological sites that are seen to represent the evolution of an ancient cultural tradition and the traces of sedentary human occupation of the Gulf region of the Arabian Peninsula from the Neolithic Period up to the present. Al-Ahsa Oasis landscape represents the different phases of the oasis's evolution and the interaction of natural and cultural heritage.

The need for biodiversity conservation in Saudi Arabia has become a rising priority, where good practice and scientific knowledge is highly required. The present study highlights of the plant diversity in Al-Hassa region, in terms of species composition, distribution in different habitats, life forms, chorotypes and their economic uses. This will determine the importance of Al-Hassa area as a hottest hotspot and thus to pinpoint super priorities for conservation.

Materials and Methods

Study area

Saudi Arabia extends over an area of 2.25 million km^2, and occupies almost two-thirds of the Arabian Peninsula. The area occupied by the country represents about 1.5% of the total land area, about 5% of Asia and about 5% of the area of the arid zones in the world. The kingdom extends between 16º-32 º N and 35º- 56º E. It lies to the north of Iraq, Jordan and Kuwait; on the east by the Arabian Gulf, United Arab Emirates and Qatar; Oman on the southeast; and Yemen on the south and on the west by the Red Sea. Al-Ahsa, often referred to as the largest and the oldest Oasis in the Arabian Peninsula, is located in the Eastern Region of Saudi Arabia about 150 km south of Dammam and 320 km south-east of Riyadh. It extends from approximately 25° 21' to 25° 37' latitude north and from 49° 33' to 49° 46' longitude east. It embraces an L-shaped area of 320 km^2 with vertical stroke lying in a due north-south direction and the province capital, Hofuf lying in its corner. The entire cultivated area, which used to be over 20,000 ha, is not continuous at present, being interrupted around the towns of Hofuf and Al-Mubaraz in the south-western corner of oasis. During the following 15 years, this area decreased to about 8,000 ha due to salination of the soil because of over irrigation and or inadequate drainage. Alfalfa, dates, vegetables, melons, among others. were the main agricultural products [32]. Al-Hassa has a dry tropical climate, the summer months are from June to August with temperatures ranging between 35 and 45°C, which occasionally rises above 50°C, and has relatively cold winters from December to February, with temperatures ranging between 2 and 22°C [33, 34]. The average relative humidity is about 26.5%. the diurnal variation of the air-temperature is strikingly high and causes the apparent diurnal variations of relative humidity. The oasis is characterized by an arid climate with a high potential evaporation rate where the annual rainfall approximate 84.8 mml year [35].

METHODS

From spring 2020 to winter 2024, several field expeditions were conducted across multiple locations throughout Al-Hassa region to survey all identified habitat types (Fig. 1). During these surveys, the plant species were recorded. Nomenclature used within the table was based on Collenette [22], Migahid [36], Chaudhory [37]. Supplementary information was obtained from comprehensive review of published literature encompassing journal articles, reference books, graduate theses, and technical reports such as: [28, 29, 36, 37, 38, 39, 40, 41, 42]. The plant checklist was organized alphabetically following the Angiosperm Phylogeny Group (APG) IV classification system, with taxonomic verification using multiple authoritative sources. Scientific names were cross-checked against Plants of the World Online database (POWO). The plant life forms in this study were categorized using Raunkiaer [43] classification framework, following modifications proposed by Kershaw [44]. The global geographical distribution of the recorded species in the study area was determined from Zohary [45, 46]; Feinbrun-Dothan [47, 48]; Boulos [49]. This will help in assessing the rarity forms of these species. The potential and actual economic uses of wild plants were assessed on three bases; field observations, information collected from interview with local inhabitants (no human participants were involved in this study), and literature review [38, 45, 46, 47, 48, 50, 51, 52, 53, 54].

RESULTS

The recorded species in the study area, their families, life forms, chorotypes, and their uses are listed in appendix (1). The total number of the recorded species in Al-Hassa oasis was 282 species belonging to 187 genera and 58 families. About 40.8% (115 species) were annuals (20 species of them are grasses), while 59.2% were perennials ((167 species: 47 shrubs, 23 trees, 28 grasses, 9 sedges, 8 hydrophytes and 6 parasites species). Poaceae has the highest contribution to the total flora (17.0% of the total species), followed by Chenopodiaceae (12.1% of the total species), Asteraceae (9.9%), Brassicaceae and Fabaceae (5.7% each) (Fig. 2). Thirty families were represented only by one species; 6 families by two species; and 6 families by three species. The neglected palm orchards had the highest number of species (80 species = 28.4%), followed by water bodies (77 species = 27.3%), sand sheets (71 species = 25.2%), and cultivated palm orchards (66 species = 23.4%). (Fig. 3).

Figure 3.. Distribution of species in relation to the habitat types. The habitats are: LK: Lake, SM: Salt marshes, SD: Sand dunes, SS: **Sand sheets**, WB: Water bodies, CP: Cultivated palm orchards, NP: Neglected palm orchards, RS: Roadsides, RL: Rocky lands and WA: Wadis.

Table. Diversity indices. R1-'Margalef ', R2-Menhinick '', C -Simpson dominance, H' 'Shannon', N1-equality abundant 'Hill', N2-inverse Simpson 'Hill', E1- Shannon, E6-Evenness.

Habitat	RICHNESS			DIVERSITY				EVENNESS	
	N0 'Hill'	'R1'	'R2'	C	H'	N1	N2	E1	E5
Lakes	49	12.15	6.8	0.003	3.86	47.52	332	0.99	7.1
Salt marshes	44	11.23	6.49	0.002	3.77	43.31	518	1.00	12.21
Sand dunes	18	5.67	4.02	0.011	2.86	17.41	95	0.99	5.73
Sand sheets	87	19.16	9.22	0.001	4.46	86.27	1958	1.00	22.95
Water bodies	109	22.89	10.3	0.001	4.68	107.41	1554	1.00	14.59
Cultivated orchards	104	22.09	10.1	0.0001	4.64	103.26	2783	1.00	27.2
Neglected orchards	109	22.93	10.35	0.0001	4.68	108.26	3053	1.00	28.45
Roadsides	10	3.62	2.89	0.030	2.25	9.52	33	0.98	3.75
Rocky lands	7	2.73	2.33	0.056	1.89	6.61	18	0.97	3.03
Wadis	20	6.06	4.17	0.012	2.95	19.2	84	0.99	4.58
Total	**282**	**49.81**	**16.79**	**0.005**	**2.39**	**10.88**	**211**	**0.97**	**4.23**
Species richness	**55.8 ± 42.74**								
Species turnover	**5.05**								

The life form spectra of the recorded species indicated that therophytes had the highest contribution (115 species: 40.8% of the total recorded species), followed by chamaephytes (63 species: 22.3%), geophytes (39 species: 13.8%), phanerophytes (26 species: 9.2%), and hemicryptophytes (25 species: 8.9%). While hydrophytes and parasites were the lowest (2.8 and 2.1%, respectively) (Fig. 3).

Regarding the distribution of global chorotypes, the bi-regionals elements were the highest (99 species = 35.1%), followed by mono-regionals (77 species = 27.3%), while the pluri-regional (66 species = 23.4%) and cosmopolitans (33 species = 11.7%) were the lowest (Table 3). Thirty-five of the mono-regional species were Saharo-Arabian, 16 were Sudano-Zambezian elements, and another 6 species were Mediterranean elements. Two endemic species (*Caroxylon arabicum* (Botsch.) Akhani & Roalson and *Zygophyllum mandavillei* Hadidi) and 5 near-endemic (*Halothamnus bottae* Jaub. Et Spach, *Horwoodia dicksoniae* Turrill, *Limeum arabicum* Friedrich, *Matthiola arabica* Boiss. and *Zygophyllum qatarense* Hadidi) were recorded.

Table 2
Chorotype of the recorded species in Al-Hassa Oasis.

Chorotype	Mono	Bi	Pluri	Total
COSM	-	-	-	**33**
Endemic	-	-	-	**2**
Near-endemic	-	-	-	**5**
Saharo-Arabian (SA)	35	69	42	**146**
Sudano-Zambezian (SZ)	16	36	24	**76**
Mediterranean (ME)	6	37	52	**95**
Irano-Turanean (IT)	5	37	52	**94**
Euro-Siberian (ES)	1	6	22	**29**
Tropica (TR)	8	6	7	**21**
Paleo-tropical (PAL)	4	3	6	**13**
PAN	2	4	5	11
Total	**77**	**99**	**66**	**282**

Regarding the economic uses, 264 species (93.6% of the total species) have at least one aspect of the potential or actual economic uses (Table 1). 84 species have ≥ 3 (out of 5) economic aspects, of them 37 species have 4 economic aspects. Two hundred and twenty two species (78.7%) are grazed by the domestic animals, while 137 species (48.6% of total recorded species) are medicinal plants, 49 species (17.4%) are edible by man, 83 species (29.4%) are used as fuel and 57 species (20.2%) had other economic uses (Fig. 4). The economic uses of the recorded species could be arranged in a descending order as follows: grazing > medicinal **>** fuel > other uses > human food.

DISCUSSION

In the present study an attempt has been made to highlight the diverse floral resources, distribution of vegetation types and enormous floristic diversity in Al-Hassa Oasis. The recorded species in the present study (282 species) represent about 12.5% of the whole flora [22] and 49.9% of the eastern region of Saudi Arabia [38]; their genera represent 22.3%; and their families represent 38.9%. From the biodiversity viewpoint, the present study indicates that this area seems to be the richest area of the kingdom taking into account its relatively small area comparing with the area of kingdom (it represents about 0.003% of the total area of kingdom). One of the main characteristics of the vegetation cover of Saudi Arabia is its low floristic diversity. The number of plant species that recorded in the country is 2250 species, many of which are in the wetter areas of its south-western part. Which include Sarrawat mountains these species belong to 840 genera and 149 families [23, 38]. This indicates that this area should be selected as a hotspot for plant diversity in the Kingdom. Moreover, the following is a comparison between some floristic composition in the study area and other areas in Saudi Arabia are shown in the Table 3.

Table 3
Comparison between some floristic variables in the present study and the other previous studies.

Variables		Present Study	Mandaville [38]	Collenette [22]	Al-Nafei [23]
Species		282	565	2250	2172
Families		58	73	142	149
Genera		187	322	835	840
Asteraceae	%	9.9	66	9.9	10.7
Poaceae		17.0	11.7	11.6	12.1
Fabaceae		5.7	8.9	9.4	9.7
Chenopodiaceae		12.1	7.4	3.1	
Brassicaceae		5.7	8.1	3.9	

It is evident that the Poaceae, Chenopodiaceae and Asteraceae have the highest contribution, followed by Brassicaceae and Fabaceae. This result may be attributed to the large global distribution and thus the wide ecological range and efficient seed dispersal capacity of Poaceae and Asteraceae members [55]. This trend similar to the whole flora of Saudi Arabia, where these three families had the highest species in the whole flora which are Poaceae (262 species = 12.1%), Asteraceae (233 species = 10.7%), and Fabaceae (210 species = 9.7%). Similar results were also recorded by Al-Sodany et al. [56], Howladar et al. [57], Al-Yasi et al. [58], Al-Zahrani [59] and Abdel Fattah and Ali [60] in different areas of Taif Province; Al-Turki [61] on his study of the flora of Jabal Fayfa in the south western Saudi Arabia; and El-Ghanim et al. [62], and Al-Turki and Al-Olayan [63] on the study of the flora of Hail region. In addition, the members of family Chenopodiaceae may be due to the ability of these to resist drought, salinity, sand accumulation and grazing [64, 65]. The present study indicated that 30 families (51.7% of the total recorded families) were represented by only one species. These results similar to that of tropical and subtropical deserts including Saudi Arabia in which the most plant species belong to a limited number of plant families; for example, Al-Nafie [23] recorded 1586 species, which belonged to only 23 families (15.4% of the total families).

The life form spectra of the recorded species indicated that therophytes had the highest contribution, followed by chamaephytes, geophytes, phanerophytes and hemicryptophytes, while hydrophytes and parasites were the lowest. These results agree with Heneidy and Bidak [53] on Bisha, Asir region in southwestern of Saudi Arabia and El-Demerdash *et al*. [66] in the southern region; Al-Sodany et al. [56, 67], Howladar et al. [57], Al-Yasi et al. [58] on the Sarrwat mountains in the western Saudi Arabia. The dominance of therophytes and chamaephytes over other life forms in that region would seem to be the hot dry climate, topography variations and biotic influence. Also, Chamaephyte life form is able to withstand water logging, high salinity levels and a wide range of temperature variability [64, 68]. The life form distribution of plants growing in arid regions is closely related to topography and landform [69]. This picture is also congruent with the vegetation spectra in other parts of the Middle East [70, 71, 72]. On the other hand, eight hydrophytes were recorded by the present study. 3 of them (*Ceratophyllum demersum, Najas graminae* and *Potamogeton nodosus*) were recorded at Abha region, while the others (*Ceratopteris thalictroides, Myriophyllum spicatum,, Stuckenia pectinata, Ruppia maritima* and *Zannichellia palustris)*were only indicated in this area of Saudi Arabia [57] and may seem to be as a new record.

From the phytogeographical viewpoint, the present study indicates that the Saharo-Arabian Sudanian elements (146 species: 35 of them are monoregional) are the most represented chorotype, followed by the Mediterranean elements (95 species: 6 of them are monoregional), Sudano-Zambezian elements (76 species: 16 of them are monoregional) and Irano-Turanian (94 species: 5 of them are monoregional), while the other elements had a minor representation. Comparing with the other related studies, Al-Nafie [23] reported 180 species (8%) in the flora of Saudi Arabia are belongs to Saharo-Arabian Region and 88 ones to Sudo-Zambezian Region. For most authorities, the Arabian Peninsula is comprised mainly of two phytogeographical regions that cover much of the Middle East and north Africa: Saharo-Arabian Region [46] and Sudano-Zambezian Region [73, 74]. These indicate the high contribution of the species belong to the two elements. On the other hand, 31 species recorded by the present study belong to Saharo-Arabian and Sudo-Zambezian elements as a bi-regional. Unfortunately, the boundaries of these two regions in Saudi Arabia are still debatable, ill-defined and very difficult to delimit. The delimitation of the frontier between the two regions in the Arabian Peninsula in its southern part has always created some difficulties for a few biogeographers who have studied these regions [23]. These difficulties arise from the fact that the southern parts of the Saharo-Arabian region are occupied by very dry, hot and vegetationless deserts such as Al Rub Al- Khali, as well as the much more vegetated sand dunes of the Dahna and the Great Nafud. Zohary [46] suggested that these deserts could support Sudo-Zambezian species as a result of their hot climate, but are too dry to support such vegetation. In addition, many of the Saharo-Arabian elements are derived and developed from the neighboring regions, mainly the Sudo-Zambezian region in the south, and Irano-Turanian regions in the south and north-east, respectively they are developed gradually, but discontinuously under the increase of aridity since the Middle Miocene, which is believed to be a transitional period climatically between the humid early Tertiary and the arid Late Tertiary and Quaternary environments [75].

The present study recorded two endemic species, *Caroxylon arabicum* (Botsch.) Akhani & Roalson and *Zygophyllum mandavillei* Hadidi, and 5 near-endemic, *Halothamnus bottae* Jaub. Et Spach, *Horwoodia dicksoniae* Turrill, *Limeum arabicum* Friedrich, *Matthiola arabica* Boiss. And *Zygophyllum qatarense* Hadidi. Al-Nafie [23] reported that most of Saudi Arabia's lands does not seem to be an important centre of diversity. The endemic taxa in the interior part of the country are not common, where no endemic families or genera are recorded and only 19 species can be regarded as endemic (*e.g. Carnulaca arabica* and *Calligonum crinitum*), which are found in Al-Ruba Al-Khali. Most of the endemic species are found on

Sarrawat, Al-Hijaz and Madian Mountains as well as their surroundings in the western region of Saudi Arabia, which have 88 endemic species representing 82.2% of the total endemic species in the Kingdom [21]. There are many different biological or ecological indices that can be used to identify an area as ‘irreplaceable ’ or ‘biological distinct’. Among them are the species distribution criteria, overall species richness, threatened species richness, and endemic species richness; and the ecoregions-scale criteria, unusual ecological and evolutionary phenomena and global rarity of habitat types [76]. The hotspots approach’s logic behind choosing endemism as a measure of irreplaceability is straightforward: If one of the endemic species is lost in the hotspots, it is lost to the world [77]. The present study indicated that these criteria are applicable to the study area.

Biodiversity hotspots are geographic areas with an exceptionally high richness of species, including rare and endemic species. Such hotspots have deep evolutionary roots and are concentrated in areas where past climatic variability was moderate [78, 79, 80]. An important limitation of the biodiversity hotspot concept is that there may be species highly threatened with extinction that do not occur within what has traditionally been classified as a hotspot [81]. Thus, biodiversity hotspot assessments need to be paralleled by assessments of highly endangered species, and the threats they face [82]. The rich plant diversity in Al-Hassa region, however, is threatened largely due to various anthropogenic activities. Also, the Al-Hassa region, as indicated by the present study, support different vegetational types from cultivated plants to grasslands and meadows, marshes, swamps and scrub forests as well as the region abounds in large number of medicinal plants (137 species) with ethnobotanical values. Al-Hassa region is also recognized as a centre of origin of several cultivated plants like date palm. So, the present study recommends to declare Al-Hassa Oasis as a biodiversity hotspot in Saudi Arabia.

Declarations

Competing interests

The authors declare no competing interests.

Ethical approval and consent to participate

Permission was not required for data collection and publication of the study results.

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Author Contribution

All authors collected the data, designed the work, acquired and interpreted the data and drafted the work. They carried out the analysis, participated in the preparation of the manuscript, read and approved the final manuscript.

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Data Availability

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

References

1. Pimm, S. L. et al. The future of biodiversity. *Science* **269**, 347–350 (1995).
2. Thomas, C. et al. Extinction risk from climate change. *Nature*, 427 (2004).
3. IUCN. *Securing the web of life*. News story, accesses 21.02.2013, (2012). http://www.iucn.org/
4. Fisher, B. & Christopher, T. Poverty and biodiversity: Measuring the overlap of human poverty and the biodiversity hotspots. *Ecol. Econo*. **62** (1), 93–101 (2006).
5. Myers, N. et al. Biodiversity hotspots for conservation priorities. *Nature* **403**, 853–858 (2000).
6. Challenger, A. *Utilización y conservación de los ecosistemas terrestres de México* (CONABIO / Instituto de Biología, 1996).
7. Ricklefs, R. E. *The Economy of Nature* 6th edn (W. H. Freeman and Company, 2008).
8. Mittermeier, R. A. et al. *Hotspots revisited* (Cemex, 2004).
9. Contreras-Medina, R. & Luna, I. Species richness, endemism and conservation of Mexican gymnosperms. *Biodivers. Conserv.* **16**, 1803–1821 (2007).
10. Luna, I. et al. Track analysis and conservation priorities in the cloud forests of Hidalgo, Mexico. *Divers. Distrib.* **6**, 137–143 (2000).
11. Morrone, J. J. *Evolutionary biogeography, an integrative approach with case studies* (Columbia University, 2009).
12. Forest, F. et al. Preserving the evolutionary potential of floras in biodiversity hotspots. *Nature* **445**, 757–760 (2007).
13. Ortega-Baes, P. & Godínez-Álvarez, H. Global diversity and conservation priorities in the Cactaceae. *Biodivers. Conserv.* **15**, 817–827 (2006).

14. Villaseñor, J., Delgadillo, C. & Ortiz, E. Biodiversity hotspots from a multigroup perspective: mosses and senecios in the Transmexican Volcanic Belt. *Biodivers. Conserv.* **15**, 4045–4058 (2006).
15. Luna, I., Morrone, J. J. & Escalante, T. Conservation biogeography: a viewpoint from evolutionary biogeography. In: (ed Columbus, F.) Nature Conservation: Global, Environmental and Economic Issues. Nova-Science, New York (2009).
16. Mittermeier, R. A. et al. Global biodiversity conservation: The critical role of hotspots. In: Biodiversity Hotspots: Distribution and Protection of Conservation Priority Areas [Zachos, F (ed Habel, J. C.) F. E. and]. Springer Berlin Heidelberg, Berlin, Heidelberg (2011).
17. Williams, K. et al. Forests of East Australia: The 35th Biodiversity Hotspot. In: Biodiversity Hotspots: Distribution and Protection of Conservation Priority Areas [Zachos, F (ed Habel, J. C.) F. E. and]. Springer Berlin Heidelberg, Berlin, Heidelberg (2011).
18. Noss, R. et al. How global biodiversity hotspots may go unrecognized: lessons from the North American Coastal Plain. *Divers. Distrib.* **21** (2), 236–244 (2015).
19. Asaad, I. et al. Ecological criteria to identify areas for biodiversity conservation. *Biol. Conserv.* **213**, 309–316 (2017).
20. Tietje, M. et al. Global hotspots of plant phylogenetic diversity. *New. Phytol*. **240**, 1636–1646 (2023).
21. Al-Nafie, A. *Plant Geography of Saudi Arabia* (in Arabic), *Riyadh* (2004).
22. Collenette, S. *Wild Flowers of Saudi Arabia. NCWCD* (National commission for Wildlife Conservation and Development, Publication), 1999).
23. Al-Nafie, A. Phytogeography of Saudi Arabia. *Saudi J. Biol. Sci.* **15**, 159–176 (2008).
24. Vesey-Fitzgerald, D. F. The vegetation of Central and Eastern Saudi Arabia. *J. Eco*. **45**, 779–798 (1957).
25. Migahid, A. M. et al. (eds). *Proceedings of the first conference on the biological aspects of Saudi Arabia*, held at the University of Riyad, January 15–17, 1977*. Riyad: Riyad University Publications (1977).
26. El-Sheikh, A. M. & Youssef, M. M. Halophytic and xerophytic vegetation near Al-Kharj springs. *J. Coll. Sci. Univ. Riyadh*. **12**, 5–21 (1981).
27. Elsheikh, M. A., Ibragim, S. M. & Al-Solaimani, S. G. Ecological Characteristics of Plant Species at Alasfar Lake in Al-Ahsa Region Saudi Arabia. *Int. J. Agric. Innov. Res.* **5** (1), 2319–1473 (2016).
28. Shaltout, K. H. & El Halawany, E. F. Weed Communities of Date Palm in Eastern Arabia. *Qatar Univ. Sci. J.* **12**, 105–111 (1992).
29. Shaltout, K. H. & El Halawany, E. F. Vegetation analysis of the irrigation and drainage canals in Eastern Saudi Arabia. *J. Univ. Kuwait (Sci)*. **20**, 261–274 (1993).
30. Shaltout, K. H. & Mady, M. A. Current situation of the raudhas woody plant populations in the central Saudi Arabia. *Feddes Repert*. **104**, 503–509 (1993).
31. Shaltout, K. H. & Mady, M. A. Analysis of raudhas vegetation in central Saudi Arabia. *J. Arid Environ.* **34**, 441–454 (1996).

32. Al-Zarah, A. I. Water resources and agricultural development in Saudi Arabia. *J. Saudi Soc. Agric. Sci.* **7** (1), 1–12 (2008).
33. Allbed, A., Kumar, L. & Sinha, P. Mapping and modelling spatial variation in soil salinity in the Al Hassa Oasis based on remote sensing indicators and regression techniques. *Remote Sens.* **6** (2), 1137–1157 (2014).
34. Almutawa, A. A. Date production in the Al-Hassa region, Saudi Arabia in the face of climate change. *J. Water Clim. Chang.* **13** (7), 2627 (2022).
35. Hasanean, H., Almazroui, M. & Rainfall Features and Variations over Saudi Arabia, A Review. *Climate* **3**, 578–626 (2015).
36. Migahid, A. M. *Flora of Saudi Arabia* fourth edn (King Saud University, 1996).
37. Chaudhary, S. A. *Flora of the Kingdom of Saudi Arabia*, 3 Vols. Ministry of Agriculture, Riyadh (1989–2001).
38. Mandaville, J. P. *Flora of Eastern Saudi Arabia* (Kegan Paul International, 1990).
39. Shaltout, K. H., El Halawany, E. F. & El-Kady, H. F. Consequences of protection from grazing on diversity and abundance of the coastal lowland vegetation in Eastern Saudi Arabia. *Biodivers. Conserv.* **5**, 27–36 (1996).
40. Al-Sheikh, H. & Fathi, A. A. Ecological Studies on Lake Al-Asfar (Al-Hassa, Saudi Arabia) with Special References to the Sediment. *Res. J. Environ. Sci.* **4** (1), 13–22 (2010).
41. Al-Kahtani, M. A., Youssef, A. M. & Fathi, A. A. Ecological Studies on Al-Khadoud Spring, Al-Hassa, Saudi Arabia. *Pak J. Biol. Sci.* **10** (22), 4063–4068 (2007).
42. Youssef, A. M., Al-Fredan, M. A. & Fathi, A. A. Floristic Composition of Lake Al-Asfar, Alahsa, Saudi Arabia. *Int. J. Bot.* **5** (2), 116–125 (2009).
43. Raunkiaer, C. *Plant life forms* (Clarendon, 1937).
44. Kershaw, K. A. *Quantitative and dynamic plant ecology* 2nd edn (Edward Arnold, 1973).
45. Zohary, M. *Flora Palaestina*. (Parts 1 & III). Israel Acad. Sci. and Humanities, Jerusalem 1987). (1966).
46. Zohary, M. *Geobotanical Foundations of the Middle East*, 2 vols. Gustav Fischer Verlag, Stuttgart (1973).
47. Feinbrun-Dothan, N. A. *Flora Palaestina (Part III). Jerusalem*. *Isr. Acad. Sci. Hum.* (1978).
48. Feinbrun-Dothan, N. A. *Flora Palaestina (Part IV). Jerusalem*. *Isr. Acad. Sci. Hum.* (1986).
49. Boulos, L. *Flora of Egypt: 4 Vols*. Alhadara, Publishing, Cairo, Egypt (1999–2005).
50. Allred, B. W. *Training Handbook Range Management for Saudi Arabia* (FAO, 1968).
51. Danin, A. *Desert Vegetation of Israel and Sinai* (Cana Publishing House, 1983).
52. Mossa, J. S., Al-Yahya, M. A. & Al-Meshal, I. A. *Medicinal Plants of Saudi Arabia (Vol. 1)*. Riyadh, King Saud University libraries (1987).

53. Heneidy, S. Z. & Bidak, L. M. Multipurpose Plant species in Bisha, Asir region, Southwestern Saudi Arabia. *J. King Saud Univ. Sci.* **13**, 11–26 (2001).

54. Heneidy, S. Z. & Bidak, L. M. Potential uses of plant species of the coastal Mediterranean region, Egypt. *Pak J. Biol. Sci.* **7**, 1010–1023 (2004).

55. Jeffrey, C. Compositae: introduction with key to tribes. In: Kadereit JW, Jeffrey C, (Eds.), families and genera of vascular plants, Vol. VIII, Flowering Plants, Eudicots, Asterales. Springer-Verlag, Berlin (2007).

56. Al-Sodany, Y. M., Mosallam, H. A. & Al-Yasi, H. M. Floristic diversity and plant communities associated with juniper forests in high altitudes. *Int. J. Curr. Life Sci.* **4** (2), 118–133 (2014).

57. Howladar, S., Al-Sodany, Y. & Abdel Khalik, K. Species richness of the catchment area of Al-Baha region, Saudi Arabia. *Bothalia J.* **45** (5), 64–91 (2015).

58. 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.* **16** (2), 1198–1213 (2019).

59. Al-Zahrani, H. S. Study on the vegetation and ecosystem of Bani-Saad mountains, south of Al-Taif city. *Umm al-Qura Univ. J. Sci. Med. Eng.* **15**, 1–13 (2003).

60. Abdel-Fattah, R. T. & Ali, A. A. Vegetation- environment relation in Taif, Saudi Arabia. *Int. J. Bot.* **4**, 1–6 (2005).

61. Al-Turki, T. A. A prelude to the study of the flora of Jabal Fayfa in Saudi Arabia. *Kuwait J. Sci. Eng.* **31** (2), 71–145 (2004).

62. El-Ghanim, W., Hassan, L., Galal, T. & Badr, A. Floristic composition and vegetation analysis in Hail region north of Central Saudi Arabia. *Saudi J. Bio Sci.* **17**, 119–128 (2010).

63. Al-Turki, T. A. & Al-Olayan, H. A. Contribution to the flora of Saudi Arabia; Hail region. *Saudi J. Bio Sci.* **10** (2), 190–222 (2003).

64. Zahran, M. A. Ecology of the halophytic vegetation of Egypt. In: Tasks for Vegetation Science, (eds Sen, D. N. & Rajpurohit, K. S.) 3–20. Dr W. Junk, The Hague (1982).

65. Danin, A. *Plants of Desert Dunes* (Springer-, 1996).

66. El-Demerdash, M. A., Hegazy, A. K. & Zialy, A. M. Distribution of the plant communities in Tihamah coastal plains of Gazan region, Saudi Arabia. *Vegetatio* **112**, 141–151 (1994).

67. Al-Sodany, Y. M., Al-Juaid, N. S. & Kahil, A. A. Ecology of invasive species *Calotropis procera* (Ait) R.Br. in Saudi Arabia. *Int. J. Ecotoxicol. Ecobiol.* **1** (3), 127–140 (2016).

68. Beeftink, W. G. The coastal salt marshes of western and northern Europe. In: Ecosystems of the World, Chapman V.J. (Ed.), 1, 109–155. Elsevier, Amsterdam (1977).

69. Shaltout, K. H., Sheded, M. G. & Salem, A. I. Vegetation spatial heterogeneity in a hyper arid Biosphere Reserve area in north Africa. *Acta Bot. Croat*. **69** (1), 31–46 (2010).

70. Danin, A. & Orchan, A. G. The distribution of Raunkiaer life forms in Israel in relation to environment. *J. Veg. Sci.* **1**, 41–48 (1990).

71. Zahran, M. A. & Willis, A. J. *The Vegetation of Egypt* (Chapman & Hall, 1992).
72. El-Bana, M. I. & El-Mathnani, A. Vegetation-soil relationships in the Wadi Al-Hayat area of the Libyan sahara. *Aus J. Basic. App Sci.* **3**, 740–747 (2009).
73. Takhtajan, A. L. *The Floristic Regions of the World* (UC, 1986).
74. Konig, P. Phytogeography of south-western Saudi Arabia, (Asir, Tihama). *Die Erde*. **119**, 75–89 (1988).
75. Anton, D. Aspects of geomorphological evolution: Paleosols and dunes in Saudi Arabia. In: Quaternary Period in Saudi Arabia, (eds Jado, A. & Zotl, J.) 275–295, Vol. 2, Springer-, New York (1984).
76. Gordon, E. A., Franco, O. E. & Tyrrell, M. L. *Protecting biodiversity: A guide to criteria used by global conservation organizations* Vol. 6 (Yale School of Forestry and Environmental Studies, Global Institute of Sustainable Forestry, 2005). (Report No.
77. Kohout, M. *Evaluating the Biodiversity Hotspots Approach as a Tool for Global Conservation Planning* (Swedish University of Agricultural Science, 2013).
78. Enquist, B. J. et al. The commonness of rarity: Global and future distribution of rarity across land plants. *Sci. Adv.* **5** (11), eaaz0414 (2019).
79. Brown, S. C. et al. Persistent Quaternary climate refugia are hospices for biodiversity in the Anthropocene. *Nat. Clim. Change*. **10** (3), 244–248 (2020).
80. Trew, B. T. & Maclean, I. M. Vulnerability of global biodiversity hotspots to climate change. *Glob Ecol. Biogeogr.* **30** (4), 768–783 (2021).
81. Grenyer, R. et al. Global distribution and conservation of rare and threatened vertebrates. *Nature* **444** (7115), 93–96 (2006).
82. Costello, M. J. et al. Biodiversity Hotspots. In: Climate Change: Impacts, Adaptation and Vulnerability. In: (eds Partner, H. O., Roberts, D. C., Tignor, M., Poloczanska, E. S., Mintenbeck, K., Alegria, A., Craig, M., Langsdorf, S., Loschke, S., Muller, V., Okem, A. & Rama, B.) The Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK and New York, NY, USA. (2022).

Figures

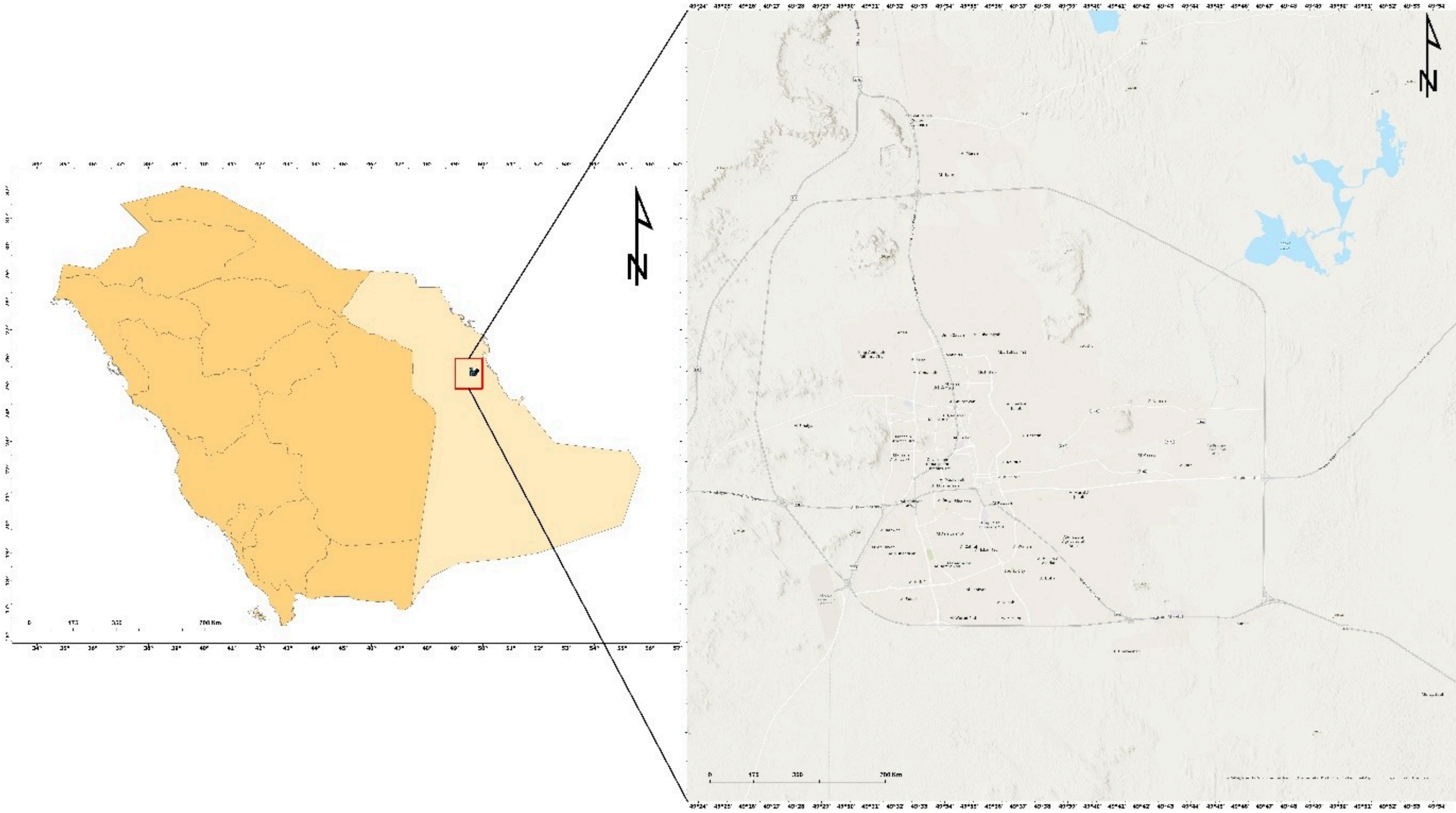

Figure 1

Map showing the study area.

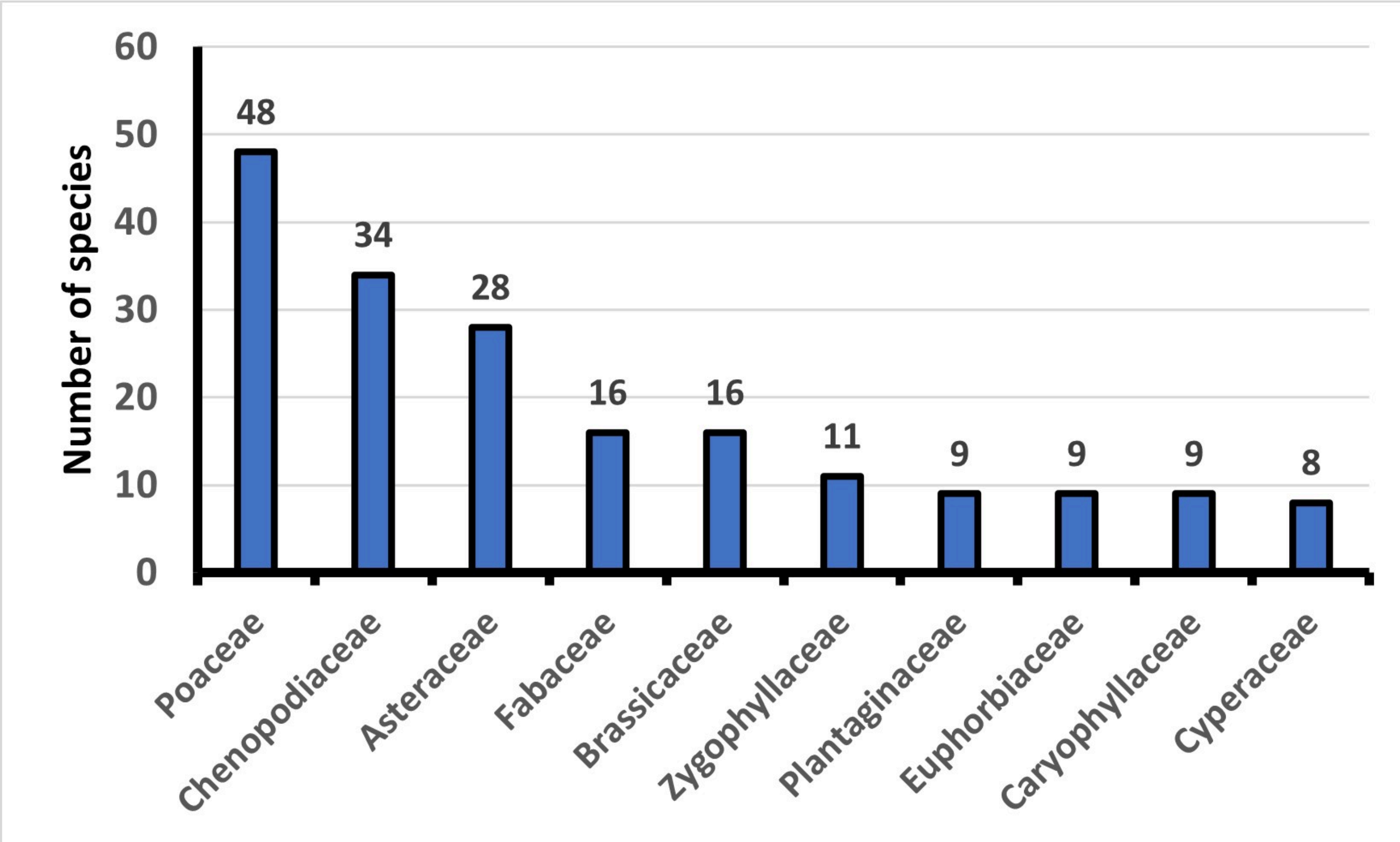

Figure 2

The highest 10 families in Al-Hassa Oasis

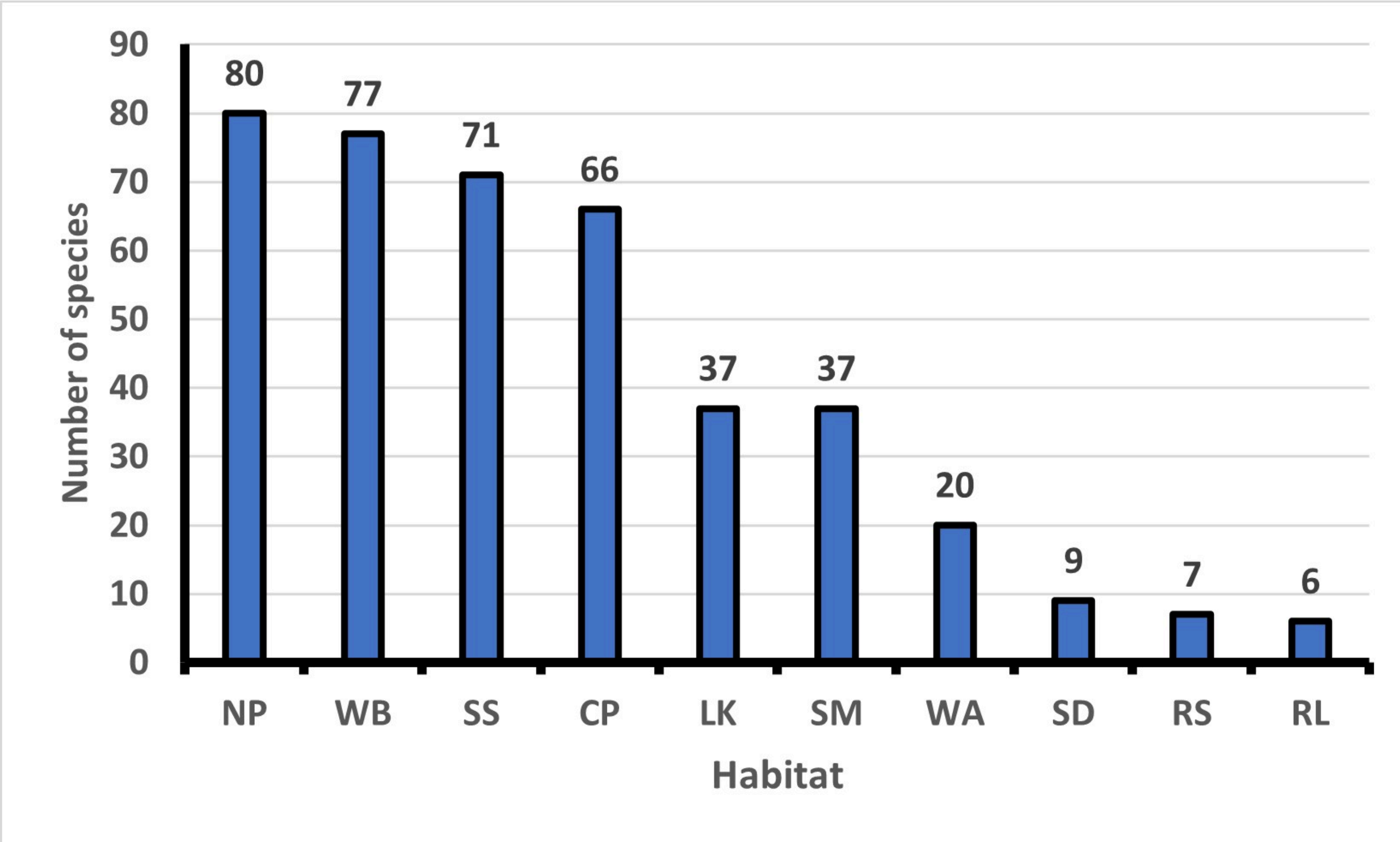

Figure 3

Distribution of species in relation to the habitat types. The habitats are: LK: Lake, SM: Salt marshes, SD: Sand dunes, SS**: Sand sheets,** WB: Water bodies, CP: Cultivated palm orchards, NP: Neglected palm orchards, RS: Roadsides, RL: Rocky lands and WA: Wadis.

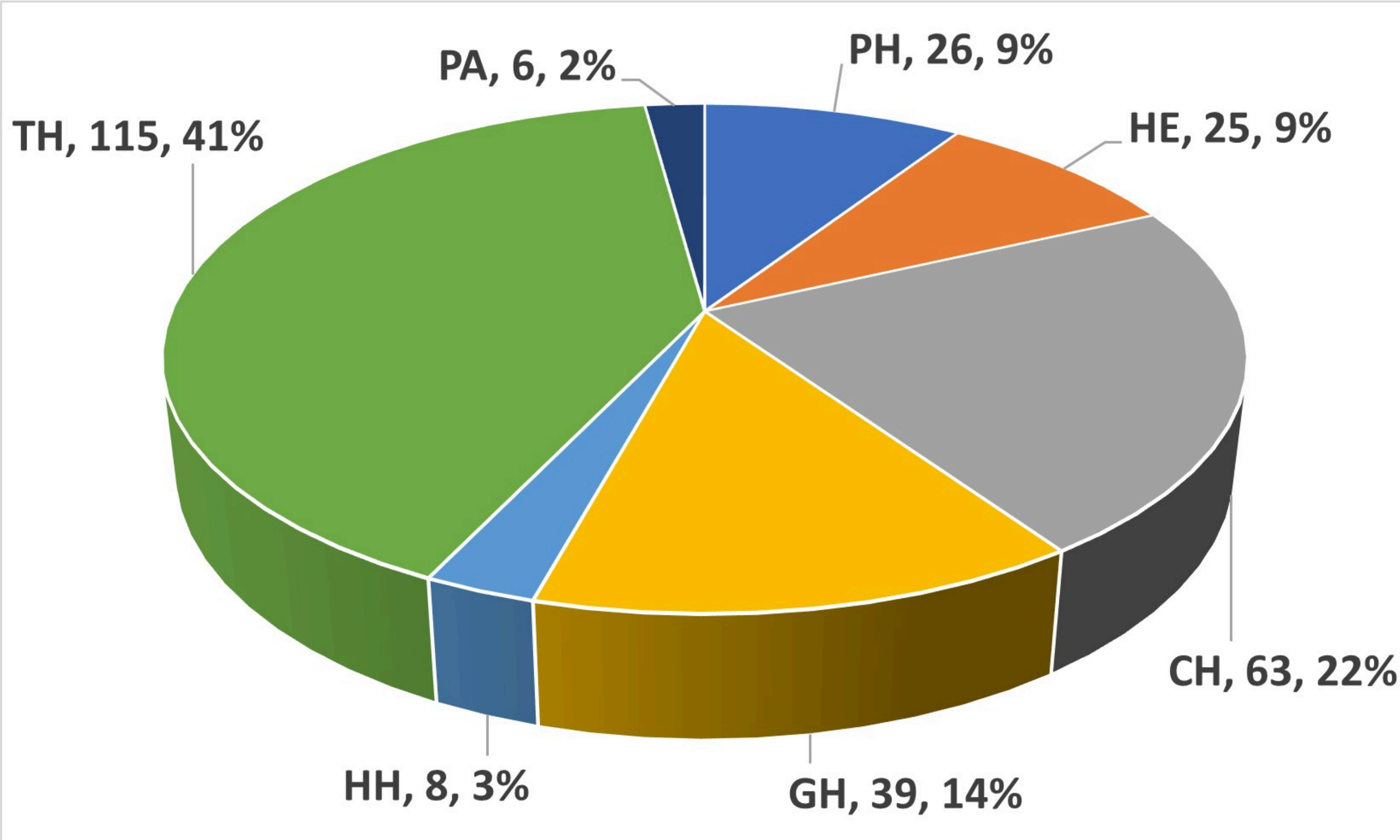

Figure 4

Life form spectra of the recorded species. PH: Phanerophytes, HE: Hemicryptophytes, CH: Chamaephytes, GH: Geo-Helophytes, HH: Hydrophytes, PA: Parasites and TH: Therophytes.

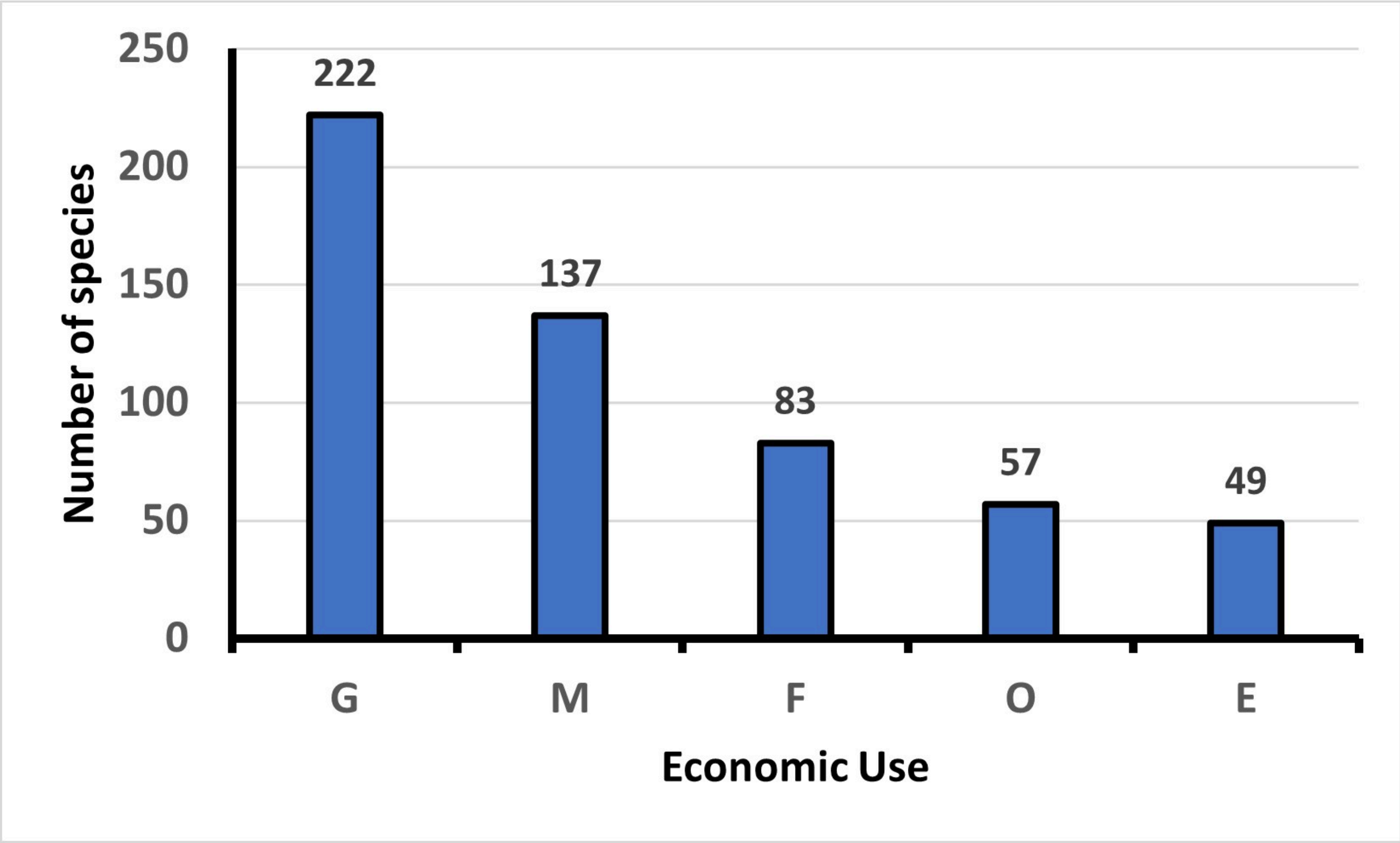

Figure 5

Economic uses of the recorded species. The uses are G: grazing, M: medicinal, F: Fuel, E: human edible and O: other uses.

Supplementary Files

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