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Ethnobotanical study of Saharo-Arabian endemic plants in the Egyptian flora

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The Saharo-Arabian region comprises an extensive area in north-western Africa. Despite its floristic rarity, it provides many goods and services. The Saharo-Arabian region has many endemic species, many of which are monotypic and Palaeogenic. Hence, this research was aimed at identifying the goods and services provided by desert ecosystems. This study recorded the presence of 126 Saharo-Arabian endemics (109 species, 17 subspecies) belonging to 87 genera and 37 families. South Sinai is the richest region with endemics, comprising 83 taxa. The most significant goods were medicine (68 taxa), grazing (43 taxa), and food (15 taxa). In addition, the most offered ecosystem services were sand stabilization (15 taxa), shading (11 taxa), and nitrogen fixation (11 taxa). Three categories of physical defense have been detected (hairy plants, spiny plants and plants with oduor. Most of the medicinal plants in this study contain flavonoids, followed by terpenes, and phenols, while Lipids, resins, and carotenoids have the lowest value. Remedies derived from medicinal plants are used to treat a variety of diseases. Cancer is treated with the highest number of medicinal taxa, followed by antimicrobial and anti-inflammatory taxa. The Saharo-Arabian endemic plants offer numerous goods and ecosystem services. Nonetheless, the study area's Saharo-Arabian plants have recently been threatened by a variety of anthropogenic factors. As a result, they require wise use as well as *in-situ* and *ex-situ* conservation measures from all relevant bodies to ensure their long-term viability and sustainability of their services.

Keywords: Endemism, Ethnobotany, Physical defense, Traditional knowledge, Saharo-Arabian region

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INTRODUCTION

The Saharo-Arabian area comprises an extensive area in northwestern Africa between the Sudanian and the Mauritanian Steppe (Hauts Plateaux) province. This belt widens significantly from Cyrenaica eastward, nearly reaching the Mediterranean Sea. This region is a major phytogeographical zone covering vast stretches of North Africa and the Arabian Peninsula. It is characterized by arid and hyper-arid desert conditions, with a distinct flora adapted to extreme drought and high temperatures. The Arab world spans approximately 13–14 million km², including 22 countries from the Atlantic Ocean (Morocco) to the Arabian Gulf (Oman, UAE, etc.). The Saharo-Arabian region includes: The Sahara Desert (most of Egypt, Libya, Tunisia, Algeria, Morocco, Mauritania, and parts of Sudan), and the Arabian Desert (Saudi Arabia, Yemen, Oman, UAE, Qatar, Kuwait, Iraq, Jordan, and parts of Syria). The approximate area of this region is equal to ~8–9 million km² (about 60–70% of the total Arab region) (White & Leonard 1991).This region has many endemic species, both genera and species, many of which are monotypic and Paleogenic, despite its floristic rarity. Gaussen (1954) comes to a quite different conclusion based on meteorological, floristic, and vegetational data: the flora of the Saharan desert exhibits an ancient Mesogean stem that has a distinct relationship to the current Mediterranean stock rather than the Paleotropic. Nonetheless, he grants this area complete autonomy. Many writers, like the author here, have given this region independence because of its old stock, even though a great number of species, even endemic ones, are descended from stocks in nearby locations (Zohary, 1973).

The Saharo-Arabian region is characterized by low species richness but high endemism due to extreme aridity. The estimated recorded flora is ~2,000–3,000 vascular plant species (Boulos, 1999–2005). In addition, ~15–20% of species are regionally endemic (Ghazanfar, 2006). The most abundant families are Amaranthaceae, Fabaceae, Zygophyllaceae and Poaceae. The plants of this region exhibit xerophytic and halophytic adaptations such as drought resistance, salt tolerance, and ephemerals (Zahran & Willis 2009). The major uses offered by these plants include medicine, food and fodder (Heneidy et al., 2017). Natural ecosystems contain a variety of services and goods that benefit human well-being and survival (Costanza et al., 1997; Reid et al., 2005). Deserts offer numerous benefits that can meet the needs of both local inhabitants and communities. However, information about these offered services and goods offered is fragmented. As a result, deserts have been largely overlooked in ecosystem valuation studies (De Groot et al., 2012). Its structure and dynamics govern the delivery of ecosystem services (Peters et al., 2006; Havstad et al., 2007).

Many plants and animals originally occurred in the Middle East, and are still extant in their centers of origin in deserts (Batanouny, 1999). Humans have exploited the potential of wild plants for food, medicine, fuel, and a variety of other practical uses (Shackleton et al., 2011; Haq et al., 2023). The collection of these wild plants plays an important role in the livelihoods of people living in less developed areas (Waheed et al., 2023). Plant utilization patterns are influenced by geographical and cultural factors, transforming human interactions with flora into a blend of behavior and wisdom (Morell-Hart et al., 2019). However, the priceless reservoir of traditional wisdom is experiencing a perilous decline because of the deterioration of ancestral cultures and the conversion of forested areas to different land uses (Haq et al., 2022). This impending loss carries the risk of forever vanishing in the wake of future progress (Arshad et al., 2024). The Saharo-Arabian region exhibits a rich interplay between geography, culture, and plant use. However, traditional botanical knowledge is rapidly eroding due to modernization, land-use changes, and cultural shifts. For example, Bedouin communities use *Haloxylon negevensis* for fuel and shelter, Omani traditional medicine employs *Rhazya greissii* for diabetes and infections (Haq et al., 2022).

As previously said, the wellbeing of future generations needs to maintain to maintain the traditional knowledge about the ethnomedicinal significance of plants across the nation's many areas. Additionally, this understanding could advance unique medical treatments. Notably, in the Saharo-Arabian region, there is not enough research examining the ethnomedicinal potential of wild plants (Mirzaman et al., 2023). This study aimed to document the diversity of Saharo-Arabian endemic plants, their utilization, goods and services and active constituents in these plants. The specific objectives are: (1) identifying the benefits provided by desert ecosystem vegetation; (2) illustrating the relationship between the ecosystem's goods and services and the socioeconomic advantages for local populations; (3) showing the relationships between the geographic distribution of these taxa and goods offered by them; (4) illustrating the different aspects of physical defense offered by these plants; and (5) showing chemical constituents and traditional uses of these taxa. It is hoped that our study will help to fill a knowledge gap about the relationship between conservation importance and ethnobotanical value of wild plants in Saharo-Arabian. The results can help inform future sustainable management and conservation efforts.

MATERIALS AND METHODS

Study area

The Saharo-Arabian region is represented throughout the majority of Egypt, except the Mediterranean coast and the Gebel Elba Mountains, according to White & Léonard, 1991. South of the Tropic of Cancer, less than 25% of Egypt's land area is located. It is located between latitudes 22° and 32° north. The majority of Egypt is in the temperate zone. Study areas include Sinai (except the El-Arish-Rafah region of the Eastern Mediterranean Coast), Nile Delta and Valley (except the North Delta coastal land), Western Desert (except the Western Mediterranean Coast), and the Eastern Desert with the Red Sea (except the Gebel Elba Mountains) (Figure 1).

Study area map

Within the Geographic Information System (GIS) framework, biogeographical localization was established using the ArcMap 10.8 software (ESRI, 2020). The vector file of the map was created using the shape file of the world map obtained from the website (https://hub.arcgis.com/search), and the floristic regions of the world were delineated on the map according to White & Léonard (1991).

Data collection and ethnobotanical survey

Ethnobotanical data on Egyptian Saharo-Arabian endemics were gathered over nearly three years (summer 2020 to spring 2023) by conducting monthly field surveys and interviewing residents within the study area (e.g., the Nile Delta, Red Sea region, Saint-Catherine, Western Oases, Assiut, Qena, Luxor, and Aswan) (Figure 2). Ethnobotanical uses were evaluated using information gathered from local interviewers. Two hundred and twenty six people from various regions were interviewed. Interviewees included residents, herbalists, and academics from universities and research centers (Table 1). Many questions have been raised about the Saharo-Arabian endemic taxa found in the area. The same questions were asked to all interviewers to record the full knowledge of each informant of the different prospects for plant uses (Appendix 2). The plants were identified using Boulos (1999-2005), and voucher specimens were kept at Kafrelsheikh University Herbarium (KFSUH) and Tanta University Herbarium (TANE). In addition, the phytogeographic regions were detected according to Täckholm (1974).

Table 1. Study districts, locations, elevation and number of local inhabitants interviewed

District	Latitude	Longitude	Altitude (M)	Ecology
Luxor - Abu Simbel	25.4817	32.401117	137	Desert land
	25.21855	32.4222	141	Desert land
	25.322667	32.4732	138	Desert land
	25.215967	32.538917	116	Desert land
	25.215967	32.538917	116	Desert land
	24.874167	32.6554	154	Desert land
	24.7699	32.679533	165	Desert land
	24.4563	32.7468	173	Desert land
	24.35	32.7694	174	Desert land
	23.970067	32.756817	188	Desert land
	23.904867	32.5193	216	Desert land
	23.76565	32.47375	217	Desert land
	23.571817	32.363483	227	Desert land
	23.497717	32.28275	253	Desert land
	23.073617	31.831617	280	Desert land
	22.901983	31.589233	246	Desert land
	26.16545	32.805233	133	Desert land
	22.8043	31.454617	200	Desert land
	22.796417	31.446633	209	Desert land
	22.768633	31.440117	205	Desert land
	22.740267	31.460033	193	Desert land
	22.72615	31.470583	193	Desert land
	22.699217	31.46785	191	Desert land
Qena - Luxor	25.6221	32.69885	133	Desert land
	25.628267	32.701267	124	Desert land
	25.698033	32.80915	167	Desert land
	25.740417	32.818783	152	Desert land
	25.816967	32.897233	155	Desert land
	26.1167	32.862833	154	Desert land
	26.16545	32.805233	133	Desert land
Assiut- Qena	26.9804	31.0959	275	Desert land
	26.96425	31.124917	269	Desert land
	26.69375	31.234117	317	Desert land
	26.414283	31.5388	291	Desert land
	26.374283	31.6076	196	Desert land
	26.352567	31.638467	186	Desert land
	26.3601	31.6797	145	Desert land
	26.107417	31.9748	102	Desert land
	26.048483	31.984033	108	Desert land
	25.978	32.178767	104	Desert land
	25.461467	32.257433	116	Desert land
	26.117767	32.720417	105	Desert land
Beni Suif- Assiut	29.26025	30.9286	51	Desert land
	29.161133	30.877067	54	Desert land
	29.14585	30.86195	60	Desert land
	29.0342	30.799383	92	Desert land
	29.03465	30.79855	91	Desert land
	29.034867	30.796517	93	Desert land
	28.952267	30.7655	74	Desert land
	28.83685	30.71745	84	Desert land
	28.82535	30.713617	91	Desert land
	28.622367	30.619817	72	Desert land
	28.28075	30.55835	81	Desert land
	27.883217	30.5551	151	Desert land
	27.79395	30.565717	153	Desert land
	27.61665	30.6389	135	Desert land
	27.590517	30.653783	147	Desert land
Hurghada- Qena	27.328367	33.6353	67	Desert land
	27.304883	33.605	95	Desert land
	27.27705	33.520533	182	Desert land
	27.234733	33.41955	317	Desert land
	27.229083	33.4117	326	Desert land
	27.221567	33.387033	327	Desert land
	27.223117	33.37575	337	Desert land
	27.19865	33.35925	386	Desert land
	27.166683	33.332667	454	Desert land
	27.150433	33.312167	486	Desert land
	27.121833	33.297767	559	Desert land
	27.1216	33.2782	573	Desert land
	27.085867	33.24	602	Desert land
	26.939517	33.090933	404	Desert land
	26.732633	32.905067	259	Desert land
	26.64115	32.832933	271	Desert land

	26.577517	32.76935	191	Desert land
	26.57815	32.770233	192	Desert land
	26.586017	32.752817	193	Desert land
	26.301283	32.77595	127	Desert land
	26.30055	32.775967	119	Desert land
	26.375367	32.78845	152	Desert land
	26.433533	32.80335	157	Desert land
	26.462133	32.793583	169	Desert land
	26.521017	32.78675	187	Desert land
	26.179883	32.7779	128	Desert land
The New Valley	24.4333	30.55	319	Desert land
	25.5	27.75	332	Desert land
Bahariya - Siwa Road	27.8	28.5833	218	Desert land
Qattara depression	29.5	25.4333		Desert land
	29.4	25.7875		Desert land
	29.2597	25.7808		Desert land
Near Moghra lake	30.2333	28.9167		Desert land
Wadi El Natrun	30.5	30.5	28	Desert land
Helwan	29.9036	31.466	303	Desert land
Qattamiya- Ain Sokhna Road	29.8206	31.8902	336	Desert land
	29.4783	32.0199	884	Desert land
	29.1515	32.1188	884	Desert land
South of Suez	28.9245	32.2946	408	Desert land
Alminya desert	27.9148	32.4923	195	Desert land
Sohag	27.282	32.6241	486	Desert land
El hassana North Sinai	30.2927	32.9973	463	Desert land
South Sinai	29.8927	32.9348	662	Desert land
	29.6291	33.3551	777	Desert land
	28.4607	33.7448	773	Desert land
	28.4737	34.2776	1092	Desert land
	28.3508	33.7899	1000	Desert land
Wadi Degla	29.9535	31.350467	111	Wadi
	29.922267	31.602	431	Wadi

Additionally, the gaps were filled depending on Literature reviews which include: (Shaltout et al., 2010; Morgan et al., 2014; Yusufoglu et al., 2014; El-Shabasy, 2016; Mohammed et al., 2017; El-Khalafy, 2018; Shaltout et al., 2018; Abdel-Kader et al., 2018; Abdelwahab & Ashour, 2018; Mahran et al., 2020; Marzouk et al., 2020; Saleh et al., 2020; Haggag & Elhaw, 2022; El-Khalafy, 2023; Shaltout et al., 2023; El-Khalafy et al., 2023; Kamel et al., 2023). Databases that were used in this study include Plants for a future (PFAF; https://pfaf.org/user/Default.aspx), Useful Tropical Plants Database (https://tropical.theferns.info/) and Plant use (http://uses.plantnet-project.org/). Furthermore, the key chemical ingredients were found based on the existing literature (e.g., Bailey & Danin, 1981; Batanouny 1999; Middleditch, 2012; Çarıkçı, 2013; Arora, 2013; El-Seedi et al., 2013; Bahmani et al., 2014; El-Shabasy, 2016; Boutaghane et al., 2016; Li et al., 2019; Ayalew et al., 2022). The used sources were shown in detail in Appendix 1.

RESULTS

The endemic flora of the Saharo-Arabian region in Egypt encompasses 126 plant taxa, including 109 species and 17 subspecies, belonging to 87 genera and 37 botanical families. The most included genera are: *Silene* (9 taxa), *Astragalus* (7 taxa), and each of *Allium*, *Bellevalia*, *Dianthus*, *Helianthemum*, *Verbascum* and *Zygophyllum* (3 taxa). Gymnosperms are represented by 1 family (Ephedraceae), one Genus, and one subspecies. The endemic plants of Egyptian Saharo-Arabian endemics were recorded in 9 Phytogeographical regions of Egypt. Sinai (South Sinai) is the richest region with endemic species (83 taxa), while the Red Sea and Nile Delta regions are the least represented (each of 5 taxa) (Figure 3).

In the current study, 93 taxa (73.8%) of Saharo-Arabian endemics are recorded to offer at least one of economic goods (Appendix 1). Their goods can be grouped into five main categories: medicine, grazing, human food, fuel, timber, and other uses (other uses include oils, perfumes, etc). The most significant goods were arranged as follows: medicine (68 taxa = 54%), grazing (43 taxa = 34.1%), human food (15 taxa = 11.9%), other uses (11 taxa = 8.7%), and timber and fuel (1 taxon for each = 0.79%) (Figure 4). In terms of habitat types, the rocky habitat is the most valuable for medicinal plants (47 taxa = 37.3 %), grazing (33 taxa = 26.1%) and human food (10 taxa = 7.9%), followed by wadis, sand formation, arable lands and water bodies. On the other hand, other uses have the maximum value in rocky habitats followed by sand formations and wadis (Table 2).

Table 2. Number of Egyptian Saharo-Arabian endemic plants providing goods and services in relation to their habitats.

Habitat	Goods					
	Medicine	Grazing	Human food	Other uses	Fuel	Timber
Rocky habitats	47	33	10	9	1	1
Wadis	33	22	4	2	-	1
Sand formations	14	12	3	4	-	-
Ridges	2	2	1	1	-	-
Water bodies	6	2	2	-	-	-
Arable lands	6	1	3	-	-	-

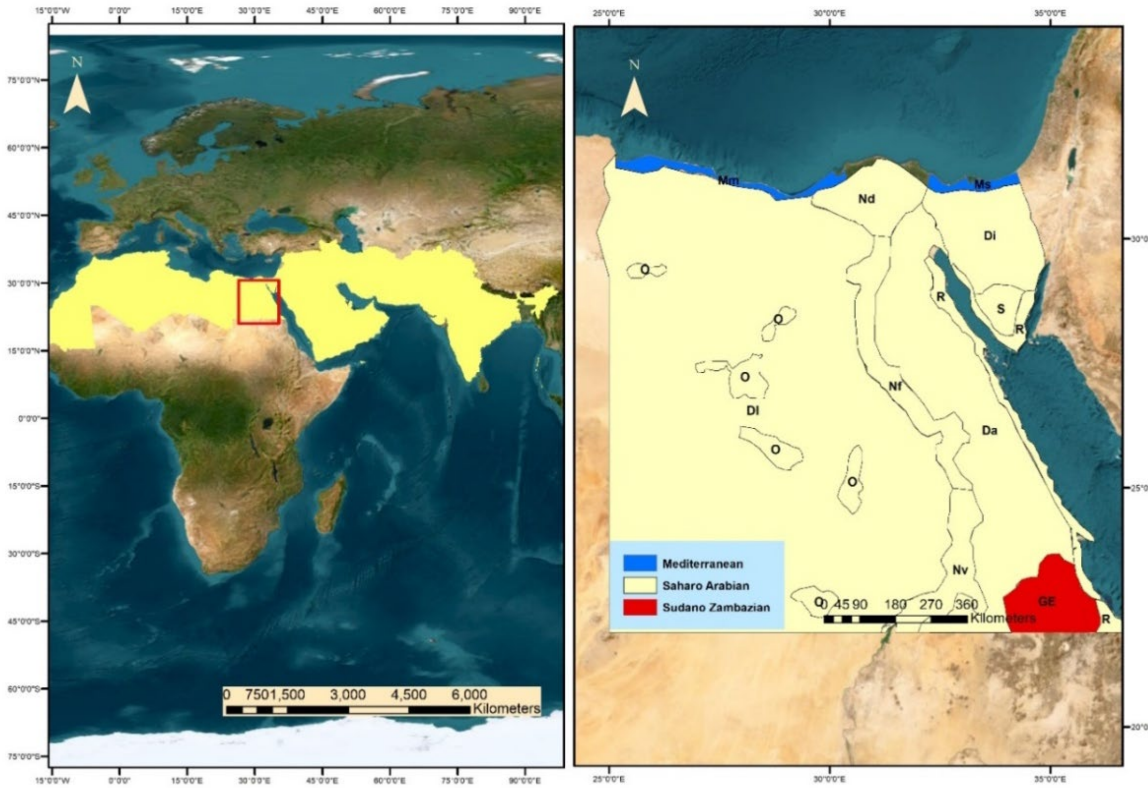

Figure 1. Map showing the boundaries of the Saharo-Arabian floristic region in the world and its sub-regions in Egypt (White & Léonard, 1991). S: south of Sinai, Di: Isthmic desert (Middle of Sinai), Da: The Arabian desert in the east of the Nile, O: Oases, R: Red Sea, Nd: Nile delta, Nv: Nile valley, Dl: The Libyan desert west of the Nile and Nf: Nile faiyum.

Among the nine phtyogeographical regions of Egypt, Sinai has the highest number of species for medicine (49 taxa= 38.8%), grazing (35 taxa= 27.7%) and human food (10 taxa= 7.9%), followed by isthmic desert (the middle of Sinai) for medicine (20 taxa= 15.8%), grazing (17 taxa= 13.4%) and human food (4 taxa= 3.1%), then by the Arabian desert (eastern desert) which has the highest percentage for medicine (24 taxa= 19%), grazing (13 taxa= 10.3%) and human food (6taxa= 4.7%) (Figures 5 and 6).

In the present investigation, 30 taxa (23.8%) are found to offer ecosystem services (Appendix 1). They could be arranged descending as follows: sand stabilization (15 taxa = 11.9%), shading (11 taxa = 8.7%), nitrogen fixation (11 taxa = 8.7%), wind breaking (3 taxa = 2.3%), esthetic value and weed (each of 2 taxa = 1.5%) (Figure 7). Regarding the phtytogeographical regions, Sinai has the largest numbers of plants that provide the ecosystem with sand stabilization (8 taxa= 6.3%), shading (8 taxa=6.3%), nitrogen fixation (5 taxa= 3.9%), followed by isthmic desert (the middle of Sinai) that have species for sand stabilization (6 taxa= 4.7%), nitrogen fixation (5 taxa= 3.9%), shading (3 taxa= 2.3%), then the Arabian desert (eastern desert) that have species for shading (5 taxa= 3.9%), sand stabilization and esthetic value (each of 2 taxa). 70 Saharo-Arabian endemics have physical defense (55.56 % of the total plant taxa). Based on the way these species defended themselves, three categories were created.

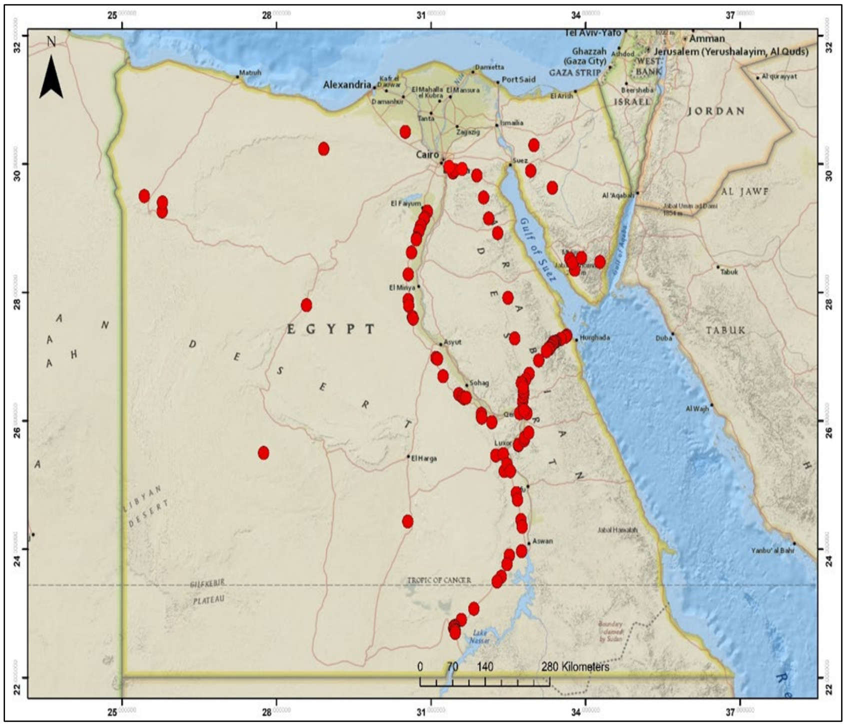

Figure 2. Distribution of the sampled plots in the research area.

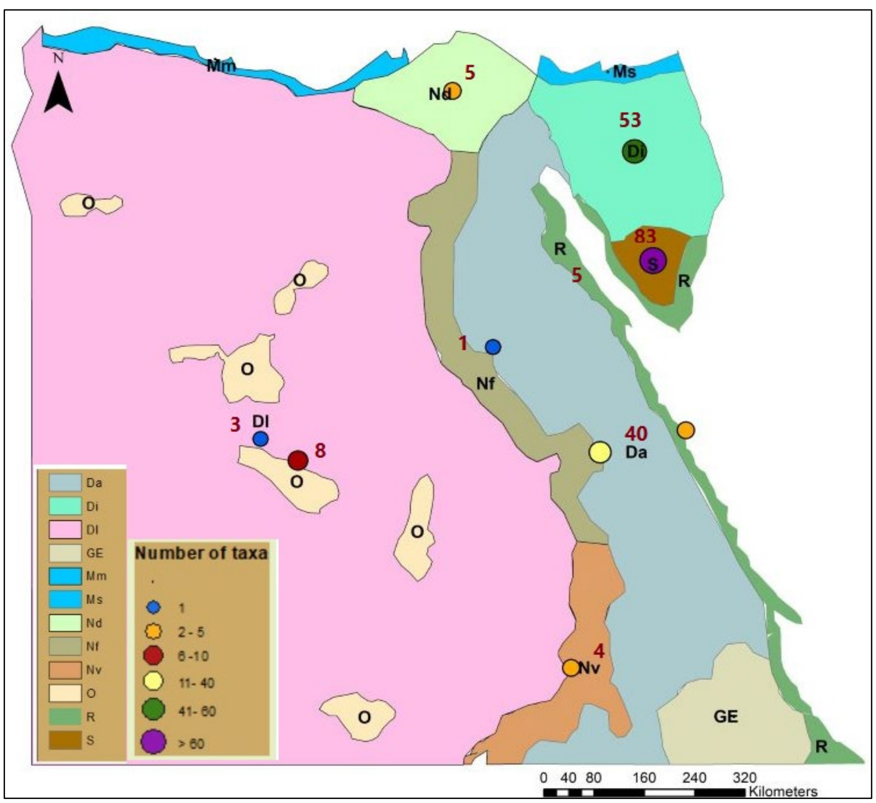

Figure 3. The allocation of endemic plants from the Egyptian Saharo-Arabian region based on Phytogeographical areas. S, south of the Sinai Peninsula; ID, Isthmic Desert; DA, the Arabian Desert located in the east of the Nile River; O, Oases; R, Red Sea and Nile Delta region; ND, Nile Delta; NV, Nile Valley; LD, the Libyan Desert located in the west of the Nile; NF, the Nile Fayum, Western Mediterranean; Mm, Ms; Eastern Mediterranean, GE; Gebel Elba.

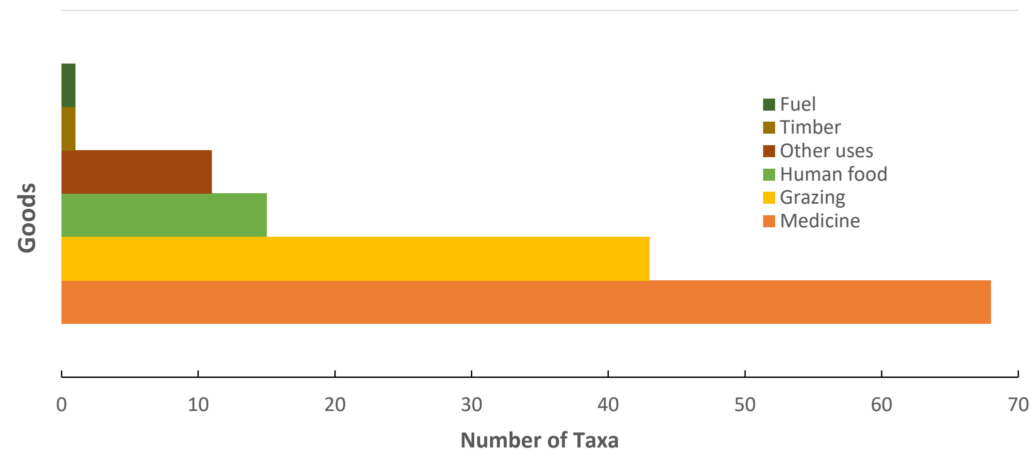

Figure 4. Number of Egyptian Saharo-Arabian endemic plants to the goods offered by them

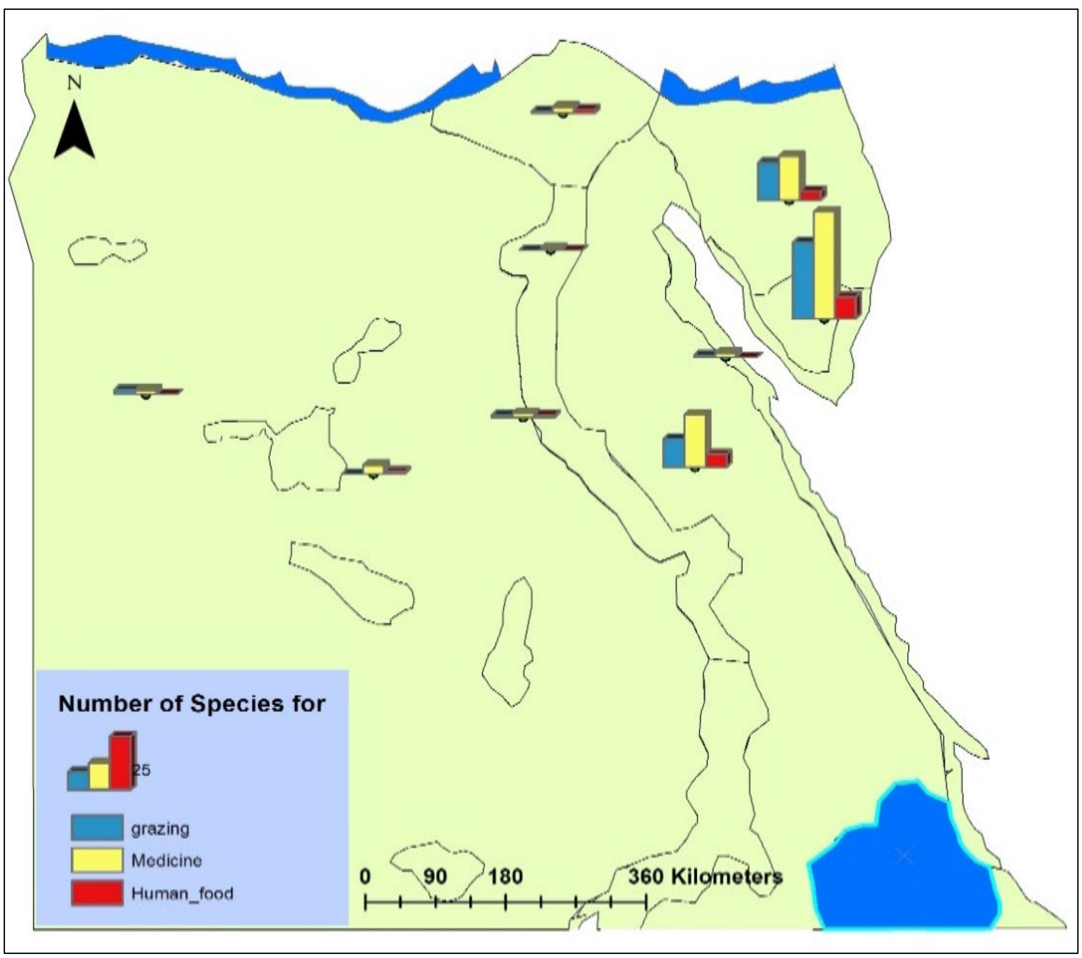

Figure 5. Number of Egyptian Saharo-Arabian endemic plants offering goods in Egypt according to Phytogeographical regions.

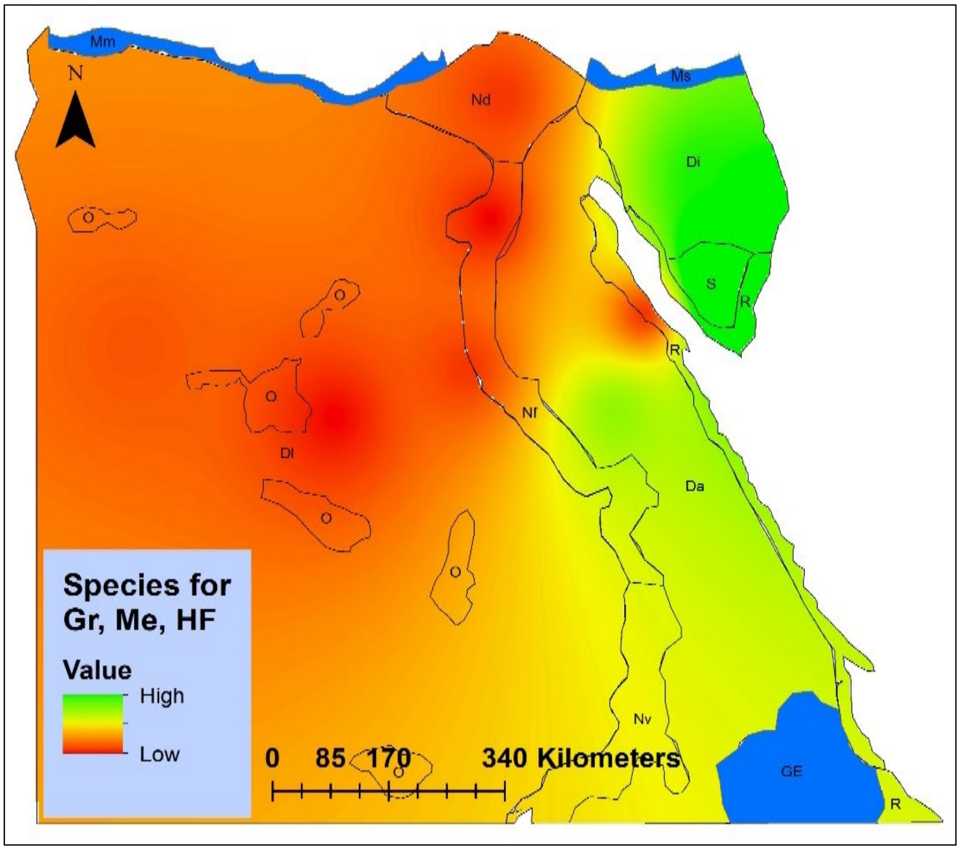

Figure 6. The distribution Egyptian Saharo-Arabian endemic plants offering goods with phytogeographical regions. Gr: grazing, Me: medicine, HF: human food.

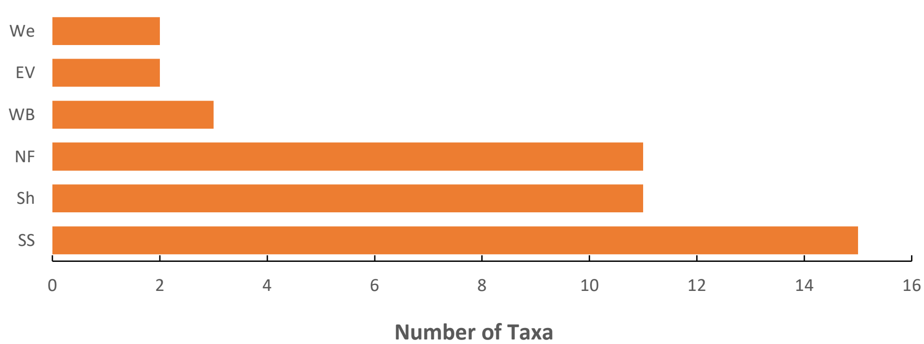

Figure 7. Number of Egyptian Saharo-Arabian endemic plants with ecosystem services. Ecosystem Services are coded as: WB: Wind breaking, SS: Sand stabilization, Sh: Shading, EV: Esthetic value, NF: Nitrogen fixation, and We: Weed.

Category I (59 species) includes hairy plants that have hairy branches, leaves, inflorescence, fruits, and stem (e.g. *Anvillea garcinii* and *Chiliadenus montanus*). In addition, category II (11 species) includes spiny plants that have spiny branches, leaves, inflorescence, and fruits (e.g., *Polygala sinaica* var. *glabrescens* and *Galium sinaicum*). Finally, Category III (3 species) includes plants with odor (e.g., *Hyoscyamus boveanus*) (Figure 8 and Table 3). In this study, the therapeutic uses, part used, major chemical constituents and traditional uses are defined for 56 taxa of Saharo-Arabian endemics that have medicinal value (Appendix 1). The percentage of plant parts utilized to treat different diseases is shown in Figure

Table 3. Saharo-Arabian endemics with different physical defense categories.

Category I: Hairy plants		
Agathophora alopecuroides var. *papillosa* (Maire) Boulos	*Helianthemum schweinfurthii* Grosser	*Schimpera arabica* Hochst. & Steud.
Anarrhinum forskaohlii subsp. *pubescens* D.A.Sutton	*Helianthemum ventosum* Boiss.	*Scorzonera drarii* V.Tackh.
Anvillea garcinii (Burm.f.) DC.	*Hyoscyamus boveanus* (Dunal) Asch. & Schweinf.	*Scorzonera schweinfurthii* Boiss.
Astragalus amalecitanus Boiss.	*Hypericum sinaicum* Hochst. ex Boiss.	*Silene arabica* Boiss.
Astragalus intercedens Sam. ex Rech.f.	*Lavandula atriplicifolia* Benth.	*Silene hussonii* Boiss.
Astragalus sanctus Boiss.	*Matthiola arabica* Boiss.	*Silene leucophylla* Boiss.
Astragalus schimperi Boiss.	*Micromeria serbaliana* Danin & Hedge	*Silene oreosinaica* Chowdhuri
Astragalus sparsus Decne.	*Nepeta septemcrenata* Ehrenb. ex Benth.	*Silene villosa* var. *graveolens* Sickenb.
Atractylis mernephthae Asch. & Schweinf. & Letourn.	*Origanum isthmicum* Danin	*Silene vivianii* subsp. *viscida* (Boiss.) Boulos
Ballota kaiseri Täckh.	*Origanum syriacum* subsp. *sinaicum* (Boiss.) Greuter & Burdet	*Stachys aegyptiaca* Pers.
Bufonia multiceps Decne.	*Paronychia sinaica* Fresen.	*Tanacetum sinaicum* (Fresen.) Delile ex K.Bremer & Humphries
Campanula dulcis Decne.	*Petrorhagia arabica* (Boiss.) P.W.Ball & Heywood	*Tephrosia kassasii* Boulos
Chiliadenus montanus (Vahl) Brullo	*Picris sulphurea* Delile	*Thymus decussatus* Benth.
Crepis nigricans Viv.	*Plantago sinaica* (Barnéoud) Decne.	*Tribulus kaiseri* Hosni
Crucihimalaya kneuckeri (Bornm.) Al-Shehbaz, O'Kane & R.A.Price	*Podonosma galalensis* Schweinf. ex Boiss.	*Verbascum fruticulosum* Post
Eremobium aegyptiacum var. *lineare* (Delile) Zohary	*Pterocephalus arabicus* Boiss.	*Verbascum schimperianum* Boiss.
Glinus runkewitzii Täckh. & Boulos	*Pterocephalus sanctus* Decne.	*Zygophyllum dumosum* Boiss.
Haloxylon negevensis (Iljin & Zohary) L.Boulos	*Pycnocycla tomentosa* Decne.	*Zygophyllum molle* (Delile) Christenh. & Byng
Haplophyllum poorei C.C.Towns.	*Reseda stenostachya Boiss.*	*Zygophyllum scabrum* (Forssk.) Christenh. & Byng
Helianthemum sancti-antoni Schweinf. ex Boiss.	*Salvia deserti* Decne.	
Category I: Spiny plants		
Atractylis boulosii Täckh.	*Centaurea sinaica* DC.	*Launaea spinosa* (Forssk.) Sch.Bip. ex Kuntze
Atractylis mernephthae Asch. & Schweinf. & Letourn.	*Chiliadenus montanus* (Vahl) Brullo	*Picris sulphurea* Delile
Arnebia tinctoria Forssk.	*Echinops glaberrimus* DC.	*Tribulus kaiseri* Hosni
Centaurea scoparia Sieber ex Spreng.	*Iphiona mucronata* (Forssk.) Asch. & Schweinf.	
Category I: Plant with odour		
Hyoscyamus boveanus (Dunal) Asch. & Schweinf.	*Agathophora alopecuroides* var. *alopecuroides*	*Haplophyllum poorei* C.C.Towns.

9. The most used parts of the plants for treatment of diseases are the aerial parts (35 taxa= 27.7% of the total taxa), followed by whole plant (8 taxa= 6.3 %), leaves (7 taxa= 5.5 %), roots (5 taxa= 3.9%), Bulb (3 taxa= 2.3%) and fruits (2 taxa= 1.5%). The seeds, bark, and flowers were the lowest parts (each of one taxon) (Figure 9).Plant families having the highest number of taxa with potential for use in medicine were: Lamiaceae (12 taxa), Asteraceae (11 taxa), Amaranthaceae (3 taxa), Brassicaceae (3 taxa), Apiaceae, Asparagaceae, Caryophyllaceae, Resedaceae, Zygophyllaceae and Scrophulariaceae (each of 2 taxa) (Figure 10). Regarding Major chemical constituents in the plants, the majority of the medicinal plants in this study contain flavonoids (35 taxa= 27.7%), followed by terpenes (28 taxa= 22.2%), phenols (27 taxa=21.4%),glycosides (21 taxa= 16.6%), essential oils (15 taxa= 11.9%), alkaloids (12 taxa= 9.5%), saponin (11 taxa= 8.7%), tannins (10 taxa= 7.9%), carbohydrates (7 taxa= 5.5%), proteins and lignans (4 taxa= 3.1%), coumarins (3 taxa= 2.3%) and vitamins (2 taxa= 1.5%). Lipids, resins, and carotenoids have the lowest value (each of one taxon) (Figure 11). Remedies derived from medicinal plants are used to treat a variety of diseases. Cancer is treated with the highest number of medicinal plant species (46 taxa= 36.5 %) (e.g., *Ducrosia ismaelis* , *Bellevalia flexuosa* var. *galalensis*, *Chiliadenus montanus*), followed by antimicrobial taxa (35 taxa= 27.7%) (e.g., *Muscari longipe*s subsp. *negevense*, *Centaurea scoparia*), antiinflammation (21 taxa= 16.6 %) (e.g. *Echinops glaberrimus*, *Iphiona mucronata*), digestive system (14 taxa= 11.1 %) (e.g. *Matthiola arabica*, *Teucrium decaisnei*), Diabetes (9 taxa= 7.1 %) (e.g., *Agathophora alopecuroides* var. *alopecuroides, Haloxylon negevensis*), Nervous system (8 taxa= 6.3%) (e.g., *Eremobium aegyptiacum* var. *lineare*, *Origanum syriacum* subsp. *sinaicum*) , Pain (7 taxa= 5.5%) (e.g., *Asphodelus refractus*, *Anthemis scrobicularis*), Circulatory system (6 taxa= 4.7%) (e.g., *Daucus sahariensis*), Urinary system (4 taxa= 3.1%) (e.g., *Nepeta septemcrenata*), fever (3 taxa= 2.3%) (e.g., *Centaurea sinaica*) and skin disease (2 taxa= 1.5%) (e.g., *Salvia deserti*) (Figure 12). Different plant parts are utilized to treat many diseases. Aerial parts are the most used parts of plants that are utilized as antioxidant, antimicrobial and antiinflammation and treatment of Diabetes, digestive system and pain followed by whole plant and leaves that are used as antimicrobial, Roots that can be used as antioxidants and bulb that is used as antimicrobial (Figure 13).

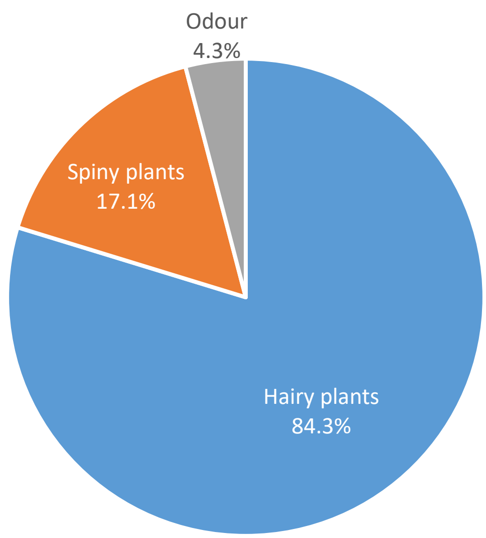

Figure 8. Physical defense of the Egyptian Saharo-Arabian endemic plants.

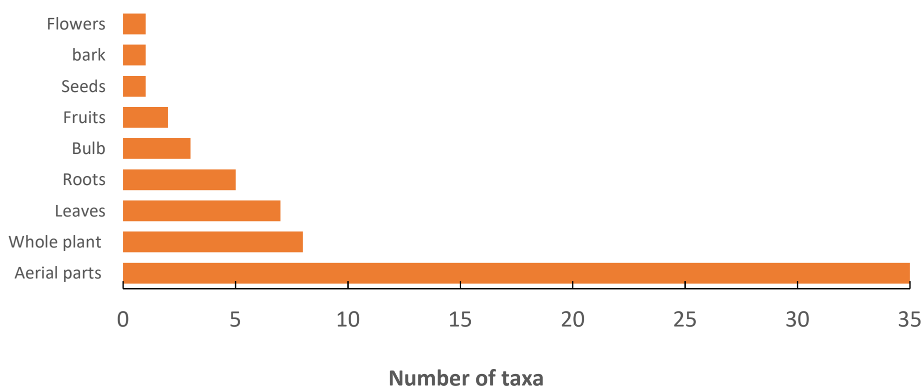

Figure 9. Number of Egyptian Saharo-Arabian endemic plants in relation to the used part for the treatment of diseases

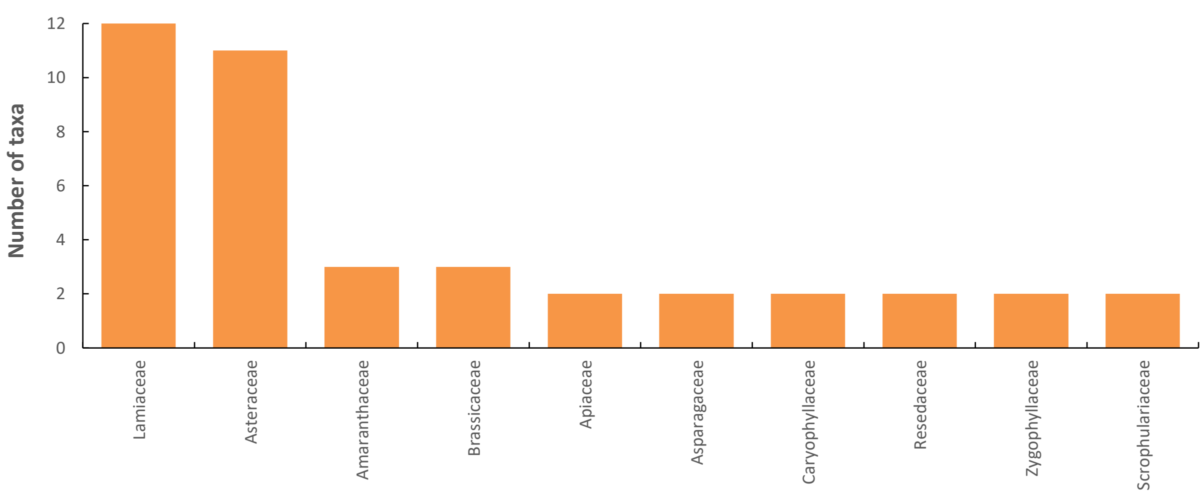

Figure 10. Families that having more than one (> 1) of medicinal Egyptian Saharo-Arabian endemic plants.

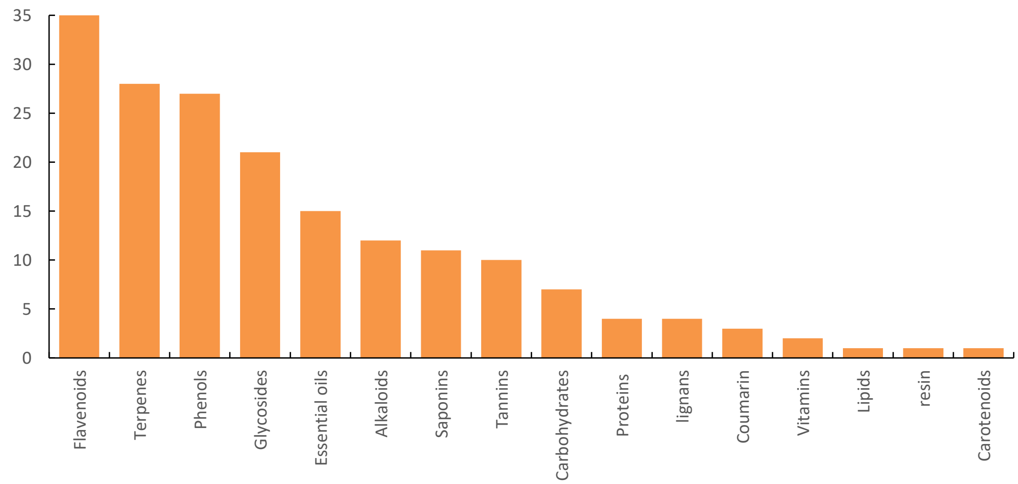

Figure 11. Number of Egyptian Saharo-Arabian endemic plants in relation to the chemical constituents of them.

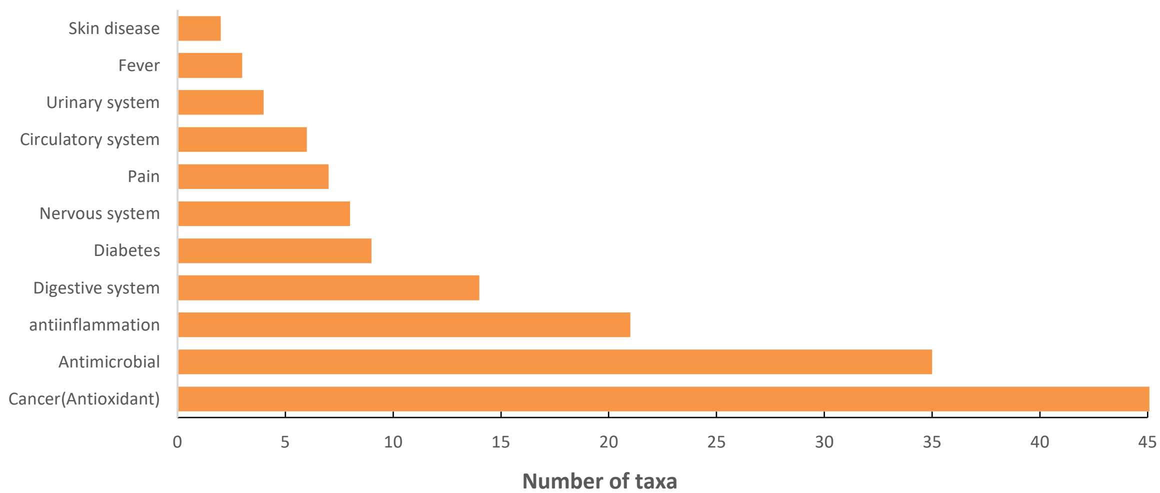

Figure 12. Number of Egyptian Saharo-Arabian endemic plants in relation to the diseases treated by them.

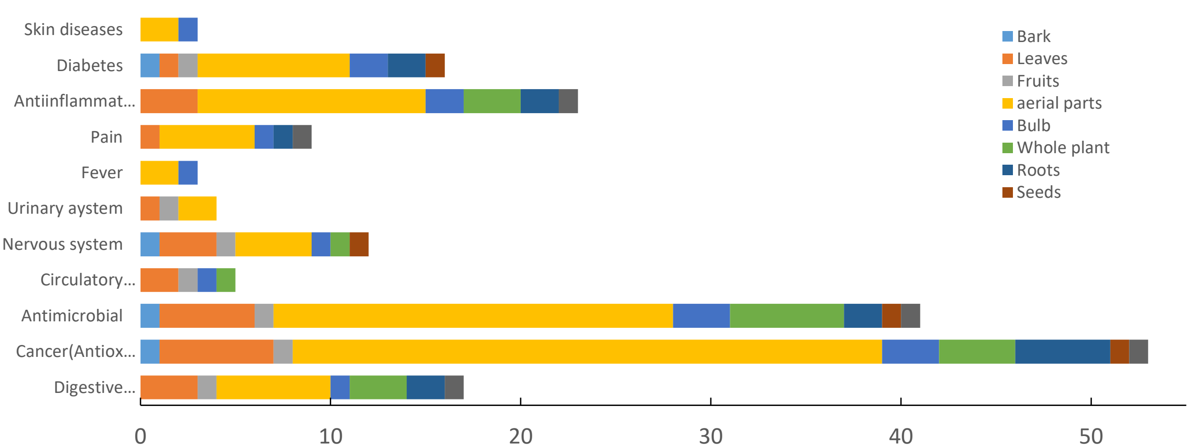

Figure 13. The relationship between diseases and the parts used to treat them.

DISCUSSION

Endemic plants are especially valuable for researching the evolution of flora and vegetation across different regions, as they are a key part of biodiversity and act as critical indicators for locating high-value biodiversity hotspots (El-Khalafy et al., 2021 and b). The Saharo-Arabian region, which includes Egypt's arid and semi-arid zones, hosts a unique assemblage of endemic plant species that contribute significantly to biodiversity and ecosystem services. These plants are not only ecologically vital but also provide essential goods and services, including medicinal uses, food, fodder, fuel, and raw materials for traditional crafts. Among these benefits, medicinal applications are particularly prominent, with many species historically used in folk medicine to treat various ailments (Batanouny, 2001; Abd El-Ghani et al., 2017). Additionally, some endemic plants serve as sources of timber, forage for livestock, and even as ornamental species, supporting both local livelihoods and ecological stability (El Hadidi, 2000; Zahran & Willis, 2009). The plant diversiy of the Saharo-Arabian endemic plants in Egypt was assessed by the study of Abo Hatab et al. (2024). It indicated that Egypt includes 126 Saharo-Arabian endemic taxa belonging to 87 genera and 37 families. Sahara regional subzone (SS1) distributes all the 126 endemic species, Arabian regional subzone (SS2) owns 79 taxa, and Nubo-Sindian subzone (SS3) distributes only 14 endemics (Abo Hatab et al., 2024).

Despite their ecological and economic importance, many Saharo-Arabian endemics in Egypt face threats from habitat destruction, overgrazing, and climate change, highlighting the need for conservation efforts. Understanding the goods and services provided by these plants is crucial for sustainable management and biodiversity preservation in this fragile ecosystem. This study stands apart from most prior research as it focuses exclusively on the Saharo-Arabian floristic region. All endemic species had at least one potential or actual economic value. Medicinal uses were the most common benefit, accounting for 54% of the species, whereas timber and fuel sources were the least represented, with only one taxon (0.79%) documented.

The present study indicated that wild edible plants are valuable resources for improving food and nutritional security and income of households living in dryland areas, as individuals living in rural areas obtain a large amount of their food and energy needs from different native trees and shrubs that are not grown intentionally. Wild plants assume importance as alternative sources of food, especially in the areas receiving frequent droughts. For many years, the value of wild edible plants in developing countries' subsistence agriculture, as a food supplement or a means of survival during drought and famine, was overlooked. Wild plants can supplement nutritional requirements, especially vitamins and micronutrients. Income and employment can be obtained from the sale or exchange of their fruits, leaves, juice and local drinks. The indigenous nature of these species confers upon them a high degree of adaptability to the local environment and cultural practices. Consequently, they exhibit robust growth with limited requirements for external inputs such as fertilizers and pesticides, making them suitable for integration into sustainable agricultural systems (Ruffo et al., 2002).

Healthy plants can contribute to ending hunger, decreasing poverty, preserving the environment, and promoting economic growth. The health of plants is essential for maintaining the health of humans and animals and plays a crucial role in the intricate relationships between the environment, humans, and animals. Acknowledging the significant importance of plants in public health, the United Nations designated 2020 as the International Year of Plant Health (IYPH). Ensuring the well-being of plants is crucial for both human and animal health, playing a key role in ensuring food security and safety, sustaining livelihoods in plant-based farming, providing pharmaceutical resources, and contributing to the creation of healthy environments (Savary et al., 2019; Strange & Scott, 2005). Droughts frequently occur in dry regions. Plants have developed various strategies to cope with drought, with many genes related to this characteristic already identified in both model and cultivated plants. Certain genes have been effectively integrated into cultivated plants to enhance their ability to withstand drought. Plants that are indigenous to dry landscapes may have different forms of mechanisms for withstanding drought in comparison to plants that thrive in moderate temperatures or commonly used plants as models. Furthermore, various genes associated with drought can also be uncovered (Trejo-Calzada et al., 2019).

Regarding the national phytogeographical regions in the present study, Sinai (especially South Sinai, SSI) has the highest number of Saharo-Arabian endemics (65.9%). The most important area of endemism in Egypt is Saint Katherine Protectorate (SKP) in (SSI) (Zohary, 1973), due to its wet climate (Danin, 1988) and physiographic features that determine specific microhabitats, which function as refugia in the deserts (Danin, 1999; Khedr, 2006; Mosallam, 2007; Moustafa et al., 2001). SKP stands out for the most interesting climate in Egypt and considerable outcrops in high altitudes rocky surfaces, which help the specification and restriction of endemic and rare taxa (Moustafa et al., 2001; Moustafa & Klopatek, 1995). In addition, high altitudes in this region hinder the dispersion process of the propagats, which often tends to increase endemic and almost endemic species (Shaltout et al., 2020). This study categorizes the goods offered into five main groups:

Medicinal taxa

Among the species identified in the study area, 68 taxa (nearly 54% of the total) were utilized for medicinal applications. Additional research has documented a significant variety of medicinal plants in Egypt. For instance, Heneidy & Bidak (2004) identified 230 plant species in the Western Mediterranean area, with 206 of them being recognized for their medicinal applications. Medicinal plants are utilized to address various ailments in both rural communities and urban populations across Egypt (Appendix 1). This is due to the chemical constituents of Saharo-Arabian endemic plants may have evolved a wide range of unique secondary metabolites to adapt to their environment and climatic conditions, making them a valuable source of novel lead chemicals for drug development. Thirteen compounds from different classes of natural products, including phenols, alkaloids, iridoid glycosides, and more, have been extracted from the endemic flora of the Saharo-Arabian region. (Ayalew et al., 2022). Chemical constituent of the endemic plants of Saharo-Arabian region is one of the natural herbal medicines rich in antidiabetic compounds (flavonoids, tannins, and phenolic) that improve the performance of pancreatic tissues by increasing the insulin secretion or decreasing the intestinal absorption of glucose, and the antihyperglycemic action can be partially attributed to the inhibition of α-amylase or other enzymes (El Hassouni et al., 2021).

Antioxidant and antibacterial properties were demonstrated by most plant extracts and essential oils (Appendix 1). As a result, they are valued as potent antibacterial agents that can be used to treat bacterial illnesses and preserve food. It's interesting to note that they demonstrated wide antibacterial activity against a variety of harmful Gram positive and Gram-negative bacteria, making them very desirable in the domains of industry and medicine. Furthermore, García-Beltrán & Esteban (2016) reported that they exhibited antibacterial action against pathogenic bacteria that infect plants, indicating their applicability in the sectors of agriculture and ecology. The therapeutic characteristics of plants can be obtained from different parts, such as leaves, roots, bark, fruits, seeds, and flowers. Various sections of a plant may hold distinct active components. In the present study, the aerial sections are the most utilized parts of plants, aligning with the finding that grazing ranks as the second most significant resource from Saharo-Arabian endemic plants; thus, to achieve sustainable development, we must regulate grazing activities in this region.

The aerial parts of *Ducrosia ismaelis* have a distinctive aroma and have been applied in the traditional folk medicine to treat skin infections and as a repellent agent for insects and reptilians (Al-Meshal, 1986). In addition, the essential oil has been shown to have interesting cytotoxic, antimicrobial, and mild antioxidant properties (Al-Meshal, 1986). Six metabolites were extracted from *Anarrhinum forskaohlii* subsp. *pubescens* ' aerial parts and found to have cytotoxic activity against the human lung carcinoma cell line (Mothana et al., 2020). Several iridoids were isolated from *Anarrhinum forskaohlii* subsp. *pubescens*. Mahran et al. (2019) identified iridoids as potential natural treatments for neurodegenerative disorders such as Alzheimer's disease. Furthermore, it has shown slight cytotoxic activity against a variety of diseases, including breast, colon, and lung tumor cell lines (Mahran et al., 2020).

Thymus decussatus is used as carminative, diuretics, urinary tract antiseptic and for kidney problems (Moustafa et al., 2014). Several studies found that *Thymus* essential oils have antimicrobial activity against important pathogenic microorganisms such as *Staphylococcus aureus* (Rasooli & Mirmostafa, 2002; Bounatirou et al., 2007), *Helicobacter pylori* and *Candida albicans* (Arora, 2013; Mohanraj & Karuppusamy, 2017). Mostafa et al. (2016) discovered that methanol extract contained some active constituents with antimicrobial and significant cytotoxic activity against Ehrlich ascites carcinoma cell and two human cancer cell lines. Furthermore, thyme oil has been shown to have antispasmodic and expectorant properties, which Khan & Abourashed (2011) attribute primarily to thymol and carvacrol. They found that thyme extracts, volatile oil, and key components possess free radical scavenging and protective effects against hepatotoxicity, DNA damage, and oxidation of brain phospholipids. Traditionally, *Launaea spinosa* is utilized for its anti-inflammatory properties. Antimicrobial tests demonstrated that its extract was effective against *Staphylococcus aureus* and *Staphylococcus epidermidis* (bacteria) along with *Candida albicans* and *Aspergillus niger* (fungi) strains (Asif et al. 2020). Additionally, the primary phenolic compounds extracted from *L. spinosa* exhibited a considerable cytoprotective effect against oxidative stress, leading to the preservation of the cell's normal redox status (Abdallah et al., 2016).

Grazing plants

Approximately 43 taxa (around In the present study, 34.1% are utilized as grazing vegetation. They assist both pet and wild animals. Field observations and data gathered regarding grazing plants and their palatability aligned with the findings of El-Khalafy et al. (2023) and Heneidy 2003). It has also been found that many of the most appealing species are currently experiencing overgrazing due to the rise in herd sizes alongside human population growth in the research area. Animal husbandry, especially the breeding of sheep and goats, is a crucial economic endeavor for the Bedouins (Abu Zeid, 1991). As noted by Heneidy & Waseem (2007) , a significant portion of the local population continued to engage in nomadic grazing, which generated food for households and income. When the plants wither, and depending on the duration of the grazing period, it is more effectively sustained by subsurface water. (e.g., Moghra Oasis; Salem & Waseem (2006).

The Saharo-Arabian area experiences significant disruption due to unmanaged human actions, such as overgrazing, excessive cutting, uprooting, along with tourism and quarrying. Due to their climate and geological features, the Saint Catherine Mountains possess a unique kind of vegetation. The flora includes many medicinal plant species, unique species, and rare species. The loss of many plant and animal species is now widely recognized, both worldwide and in Egypt, due to significant environmental changes and habitat destruction. In recent years, it has been found in South Sinai that numerous plant species are at risk due to the significant effects of grazing and human activities. Ongoing overgrazing, excessive cutting, and uprooting have led to the extinction of pasture plants, a lack of trees and shrubs, and the disappearance of numerous rare and endemic species. *Silene oreosinaica* was fed upon by both domestic and wild animals (Rabei et al., 2016). *Buffonia muticeps* experienced harmful overgrazing, leading to the degradation of its productive organs (Omar, 2017a). It is also economically important in grazing practices as a pastoral plant (Khafagi et al., 2012). *Anarrhinum forskaohlii* subsp. *pubescens* is classified as a pastoral plant (Khafagi et al., 2012; Omar, 2017b). *Micromeria serbaliana* is used economically for grazing (Omar, 2018). *Silene leucophylla* is heavily grazed by domestic animals (Omar, 2018).

Human food and fuel plants

Local inhabitants consume various organs (such as fruits, flowers, and both vegetative and ground parts) of endemic plants. Local inhabitants consumed fifteen species within the study area (Appendix 1). For instance, the aerial parts of *Gomphocarpus sinaicus* and *Matthiola arabica* were collected and consumed in the area. *Senecio belbeysius* were gathered for human consumption. (El-Khalafy et al., 2023). *Scorzonera schweinfurthii* is eaten before flowering stage (Takruri et al., 2008). Moreover, the leaves and bulb of *Bellevalia* was consumed as vegetable in the Eastern Anatolia grasslands of Turkey (Kibar & Temel, 2016). In addition, *Origanum* is an herb recognized in the United States as a spice and natural flavor that helps diminish oxidation (Fernandes et al., 2017). Moreover, the essential oil extracted from *Origanum* is currently used as an ingredient in flavoring formulations, dietary supplements (Peter, 2012). *Matthiola* is also used as an edible plant; its flowers can be eaten as vegetables or utilised as a garnish, especially with sweet desserts (Lim, 2014). Moreover, freshly boiled pods are eaten in Puglia, Italy. In China, edible flowers are sold in health food stores and consumed as tea (Jin et al., 2016). Local communities collect *Anarrhinum forskaohlii* subsp. *pubescen*s on a small scale for traditional treatment and fuel purposes (El-Khalafy et al., 2023; Omar, 2017b). Furthermore, *Rosa arabica* is collected as fuel and has an economic importance as a pastoral plant for camels and donkeys (El-Khalafy et al., 2023; Omar, 2017c).

Ecosystem services

Thirty taxa in the present investigation (23.8%) have at least one aspect of the environmental services. Drought-tolerant plants (xerophytic vegetation) were the dominant type of natural plant life in Egypt's deserts (Zahran & El-Ameir, 2013). Sand accumulators (such as *Allium decaisnei*, *Atractylis boulosii*, and *Hyoscyamus boveanus*) help to prevent soil erosion, increase soil deposition, and improve drainage in lowlands (Seif El-Nasr & Biadak, 2005). Sand accumulators are organisms that manage movi ng sand. At times, they create effective wind barriers that reproduce on their own once settled, through se eds orby spreading root structures. Certain other spe cies are particularly effective in managing sand in sali ne environments. Most sand accumulators are phane rophytes and chamaephytes, primarily found in sand formations and salt marsh areas. Occasionally, they c reate efficient wind barriers that spread on their own via seeds or spreading root networks. (e.g., *Rosa arabica* and *Pistacia khinjuk* var. *microphylla*) (Shaltout & Ahmed, 2012). Numerous Saharo-Arabian species contribute to soil stabilization (e.g., *Anthemis scrobicularis*, *Atractylis boulosii*, and *Astragalus amalecitanus*) by developing complex root systems that anchor the soil or by creating phytogenic mats, clumps, or mounds that protect the soil surface from disturbance and offer refuge and shelter for various other species. The shade provided by trees and certain shrubs limits the growth of weeds (Shaltout & Ahmed, 2012). Eleven taxa have a role in soil fertility. Most of them belong to the family Fabaceae (e.g., *Astragalus* spp., *Trigonella schlumbergeri* and *Lotus lanuginosus*). They form a symbiotic association with species of bacteria (*Rhizobium* spp., *Bradyrhizobium* spp., and others). These bacteria take nitrogen from the air and fix it into a form that is usable by the legume plant.

Physical defense

The molecular mechanism behind induced plant defense is highly intricate, necessitating substantial reprogramming that triggers physical, biochemical, and transcriptional alterations (Anil et al., 2014). In the present study, three categories of plant defense were created. Category I includes hairy plants, category II includes spiny plants, and category III includes plants with odor. The biggest group consists of plants that feature hairy, leathery leaves or hairy stems. (e.g. *Anvillea garcinii* and *Chiliadenus montanus*). Trichomes play a role in plant defense, especially about phytophagous insects (Levin, 1973). Trichomes have been extensively researched as the primary defense mechanism against herbivores (Kaur & Kariyat, 2020). Although the chemical protective role of secretory trichomes is well recognized, the biomechanical role of non-glandular trichomes appears as another significant plant defense mechanism. Trichomes, in particular, impede insect herbivore locomotion by acting as a physical barrier as well as wounding them (Bar & Shtein, 2019). These parts can reduce palatability and thus consumption by herbivores. Grime et al. (1968) found that epidermal hairs reduce the palatability of range species or prevent food from passing through animals' guts. Furthermore, Diaz & Cabido (1997) reported that hairy plants may have drought tolerance adaptations. According to Perkins (2010), hairy plants may help to reflect more sunlight, reducing the plant's harmful heating.

The second category consists of spiny vegetation that can be viewed as species resistant to grazing (e.g., *Centaurea scoparia* and *Launaea spinosa*). The protective elements are structured as densely fibrous pointed ends or short spine-like twigs. The defensive components of this group (primarily shrubs or sub-shrubs) are developed due to herbivore assaults, while the defensive parts are initially established during the early phases of the plant's life cycle. Yet, in numerous instances, the herbivores choose or favor grazing on the protective sections of young plants; some other animals tend to favor these sections as the plant matures. For instance, the flowers of certain *Echinops* species are entirely shielded by tough spines (involucres) that should not be handled, yet animals consume them, and they seem to be very appealing, especially to camels and goats. This indicates that these defensive traits are not detrimental to certain herbivores since most mammalian herbivores tend to avoid dangerous food by relying on smell and flavor instead of looks (Heneidy & Bidak, 1999).

The third group consists of plants that produce sticky latex with an unpleasant taste and smell, along with leathery leaves that have an unpleasant odor, which decreases herbivore feeding and may influence plant palatability. They seem to be harmful to livestock, yet even poisonous plants, such as *Hyoscyamus boveanus*, are consumed once they have dried out. This conclusion is backed by the research of Launchbaugh & Provenza (1993), which discovered that mammalian herbivores can extend the influence of a toxin from one food item to another according to flavor. Nevertheless, certain toxic species are ingested by livestock (Heneidy & Bidak, 1999).

CONCLUSION

This study identified 126 Saharo-Arabian endemics (109 species, 17 subspecies) from 87 genera and 37 families. Sinai (South Sinai) is the region with the most endemic species. The most important goods were medicine, grazing and human food. In addition, 30 taxa (23.8%) were discovered to provide ecosystem services. The most important ecosystem services are sand stabilization, shading and nitrogen fixation.

Three types of physical defense have been identified: category I includes hairy plants, category II includes spiny plants, and category III includes plants with odor. Most of the recorded medicinal plants in this study contain flavonoids, followed by terpenes, and phenols. Remedies derived from medicinal plants are used to treat a variety of diseases. Cancer is treated with the highest number of medicinal plant species, followed by antimicrobial and ant-inflammatory taxa. When we talk about the species' economic and medical importance, we're talking about national wealth for the area under consideration, so adequate conservation for these species is required to ensure long-term development. The Saharo-Arabian endemic plants provide numerous goods and ecosystem services. Nonetheless, the study area's Saharo-Arabian plants have recently been threatened by several human-caused factors. As a result, to ensure their long-term viability, all relevant bodies must use them wisely and implement in-situ and ex-situ conservation measures. This study is of great importance in achieving the Sustainable Development Goals, as it highlights the pivotal role of biodiversity, particularly endemic plants in the Saharo-Arabian region, in supporting humans and the economy. The research demonstrates how these plants contribute to providing natural resources such as medicines, food, and essential ecosystem services like sand stabilization and land shading, thereby improving the quality of life and supporting the local economy. Furthermore, the sustainable use of these resources enhances ecological balance and mitigates the impact of destructive human activities, making biodiversity conservation essential for achieving sustainable development and ensuring that current and future generations benefit from these vital resources.

AUTHORS' CONTRIBUTIONS

Asmaa A. Abo Hatab, Mohamed M. El-Khalafy and Salma K. Shaltout collected, acquired and interpreted the data and drafted the work. Yassin M. Al-Sodany, Mohamed M. El-Khalafy and Asmaa A. Abo Hatab designed the work and carried out the analysis. All authors revised the manuscript. All authors read and approved of the final manuscript.

AVAILABILITY OF DATA AND MATERIALS

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

COMPETING INTERESTS

The authors declare no competing interests.

ABBREVIATIONS

KFSUH	Kafrelsheikh University Herbarium
TANE	Tanta University Herbarium
S	South Sinai
Di	Isthmic Desert
Da	The Arabian desert in the east of the Nile
O	Oases
R	Red sea
Nd	Nile delta
Nv	Nile valley
DI	the Libyan desert in the west of the Nile
Nf	Nile Faiyum
GIS	Geographic information system
Gr	Grazing
Me	Medicine
HF	Human food
Fu	Fuel
Ti	Timber
OT	Other Uses
WB	Wind breaking
SS	Sand stabilization
Sh	Shading
EV	Esthetic value
NF	Nitrogen fixation
We	Weed
Ch	Chamaephyte
Ge	Geophyte
Ph	Phanerophyte
Th	Therophyte
He	Hemicryptophyte
Ge-he	Geophyte-helophyte
RH	: Rocky Habitats
SF	Sand Formations
Wa	Wadis
Ri	Ridges
AL	Arable Lands
WB	Water Bodies

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