PLANT DIVERSITY AND COMMUNITY COMPOSITION ALONG THE PREVAILING ENVIRONMENTAL CONDITIONS IN WADI MURR AL-ZAHRAN, SOUTHWESTERN SAUDI ARABIA

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Abstract. Desert wadis serve as essential ecosystems for socioeconomic development because of their biological value, physiographic heterogeneity, and environmental gradients. The study aims to evaluate Wadi Murr, the largest wadi ecosystem in Makkah, as a plant diversity hotspot regarding floristic diversity and vegetation along the prevailing environmental gradients. Data were collected from 102 stands across 17 sampling sites, representing the vegetation physiognomy along the wadi. About 118 species related to 81 genera and 35 families have been recognized, the Poaceae family notably prevailing in dominance. Therophytes prevailed among other life forms, and biregional taxa exhibited dominance among other chorotypes. The Two-way indicator species analysis (TWINSPAN) revealed 13 distinct vegetation groups (VGs) segregation along the two Detrended Correspondence Analysis (DECORANA) axes. Seven VGs (D, F, H, I, K, L, M) were dominated by halophytic species of family Zygophyllaceae, while VG (A) was dominated by the rocky community *Capparis decidua*, and VG (B and G) was dominated by the tree's communities *Vachellia seyal* and *Senna italica*. Besides, VG (E) is dominated by a grass community (*Aristida pennei*), and VG (J) is dominated by the medicinal herb *Citrullus colocynthis*. The Principal Component Analysis (PCA) ordination explained that Cl^-, SO_4^{2-}, pH, EC, fine sand, silt, and gravel significantly influenced the plant communities. Furthermore, certain plant communities, such as *Capparis decidua* and *Senna italica* exhibited positive responses to the following soil variables: Ca^{2+}, Mg^{2+}, and Na^+. In contrast, others, such as *Tribulus pentandrus* were negatively affected by gravels, coarse sand, and fine sand. The species richness ranged from 1.3 species stand^{-1} in *Capparis decidua-Cenchrus divisus* group (VG A) to 13.1 species stand^{-1} in *Senna italica-Stipagrostis hirtigluma* (VG: G). The limited species diversity observed in certain plant communities implies the eradication of the original vegetation, emphasizing the pressing need for habitat rehabilitation.
Keywords: *flora, vegetation, diversity hotspot, soil variables, Wadis, Makkah*

Introduction

Saudi Arabia (KSA) encompasses an extensive arid territory of around 2,250,000 km^2, predominantly occupying a big part of the Arabian Peninsula. It is distinguished by its varied plant species and ecosystems (Abdel Khalik et al., 2013). Saudi Arabia (SA) is positioned approximately between latitudes 15°450 N and 34°350 N and longitudes 34°400 E and 55°450 E (Miller and Cope, 1996; Al-Shareef, 2002), and it exhibits distinct environmental characteristics, including variations in topography, geomorphology, climate, and soil (Elaidarous et al., 2022). These alterations manifest in unique ecological habitats, vegetational zones, and a diverse flora throughout the country. In the southwestern region, Saudi Arabia has a wealth of ecosystems, including rocky and sandy deserts, wadis, salt pans, meadows, and mountains (Alsherif, 2019; Galal et al., 2021) characterized by high species diversity (Fadl et al., 2015).

In arid regions, plant life is primarily located within the channels of wadis, recognized as a "runoff desert" ecosystem (Salama et al., 2013). Internationally, wadis are known as the most widespread desert ecosystem (Sayed et al., 2013). Also, it can be described as dry riverbeds that only contain water during intense rainfall or as intermittent streams (Elaidarous et al., 2022; Osman, 2014). Rainwater primarily accumulates in the low floodplains of Wadis, occasionally giving rise to wet meadows, streams, and small water reservoirs (Omar and Hassan, 2018). In particular regions of the area, the runoff from the lower sections of Wadis may be several times more than the actual rainfall (Springuel et al., 2006).

Regarding the physiographic diversity and environmental conditions of the wadi's ecosystem, their socioeconomic value is increasingly acknowledged (Moustafa et al., 1999). The vegetation of wadis is threatened due to its utilization by Bedouin populations for grazing camels, sheep, and goats (Briggs et al., 1993). Additionally, wadis serve as the primary biodiversity center within xeric ecosystems, providing habitat for grazing livestock and serving as pasture for various species (Hamed et al., 2018).

Saudia Arabia lacks lakes and rivers, and the country features numerous widespread wadis (valleys) that show physiographic irregularities, leading to parallel differences in the plant species distribution (Salama et al., 2014). Generally, the vegetation in Wadis undergoes annual variations influenced by factors like physiographic features, human impacts, moisture levels, and geographical position (Siddiqui and Al-Harbi, 1995). The vegetation composition of SA is notably rich, representing a blend of Asian, African, and Mediterranean Irano-Turanian plant species. The western mountainous region of Saudia Arabia exhibits the highest levels of species diversity (Collenette, 1998). Numerous works have delved into the country's Flora and ecology, with contributions from Migahid (1988, 1989, 1990), Collenette (1999), Chaudhary (1999, 2001), and investigations specifically focusing on Wadis conducted by El-Ghanim et al. (2010), Al-Robai et al. (2017) and Elaidarous et al. (2022).

Natural vegetation is crucial to ecological sustainability by upholding biodiversity and preserving the environment (Osman and Abdein, 2019). Recently, the vegetation in Wadi Murr Al-Zahran has experienced notable alterations or faced rapid destruction, primarily attributed to extensive and unregulated human interference, livestock grazing, and excessive cutting. Generally, the primary element susceptible to degradation is the soil, which functions as the ecosystem's essential resource, ultimately resulting in regressive alterations in the vegetation (Shaltout and El-Sheikh, 2003; Guo, 2004). Consequently, we are faced with a pressing challenge to develop a viable strategy for preserving the endangered flora in these imperiled wadis. As a result, the primary goals of the current study encompass two aspects: 1) assessing the current status of the floristic inventory in Wadi Murr and 2) identifying the predominant plant communities while establishing their correlation with anthropogenic and environmental factors. Such studies can help create a plan for conserving this plant diversity hotspot in Makkah, SA.

Materials and methods

Study area

Makkah Al-Mukaramah is positioned to the east of Jeddah city, southwestern SA, at 21°26′N and 39°46′E (Abdel Khalik et al., 2013). It is located within a fragile system amidst wadis along the southwestern mountains of SA (Al-Eisawi and Al-Ruzayza, 2015). Wadi Murr Al-Zhran is the largest of the three major basins that cross Makkah region (*Fig. 1*). It extends from the northeast of Makkah to the west as an arch, and its basin covers about 5684.12 km^2. It is located approximately 40 Km from Makkah Al-Mukaramah city and between latitudes 21°13` 25” - 21° 08` 44” N and longitudes 39° 32` 24” E - 40° 11` 33” E.

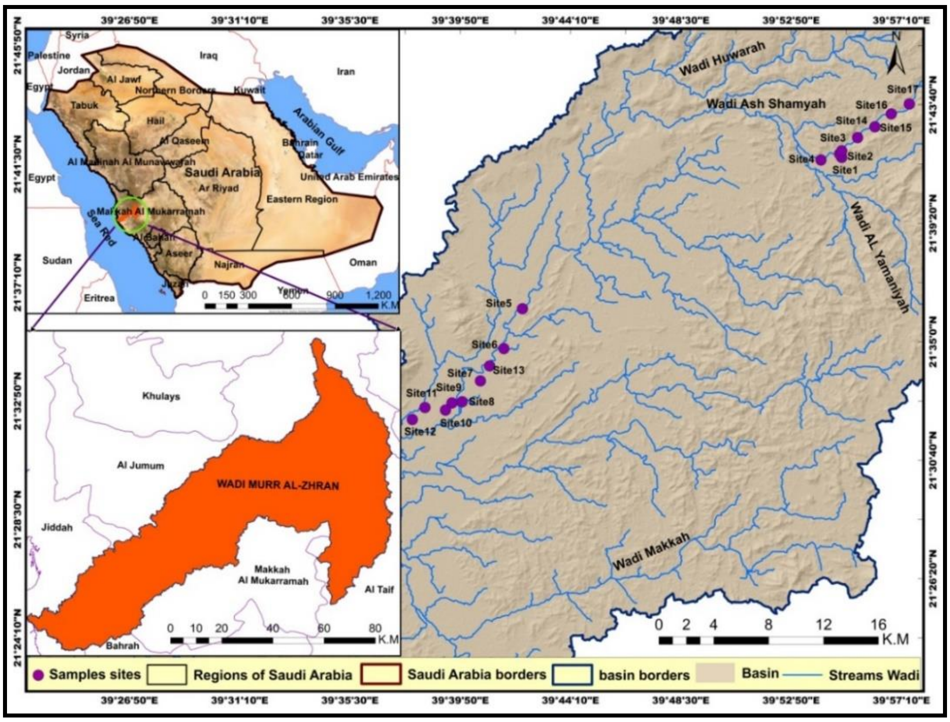

Figure 1. *Location map of Wadi Murr Al-Zhran showing the sampled sites*

The climate in the examined region is arid and tropical, as depicted by the climate chart (*Fig. 2*), indicating consistently hot and dry conditions throughout the year. The monthly average air temperature from January to June ranged between 24.5°C and 36.7°C, respectively (*Fig. 2*). Furthermore, the monthly precipitation levels exhibit significant inter-annual fluctuation from 0.2 to 27.6 mm/month in July and October, respectively.

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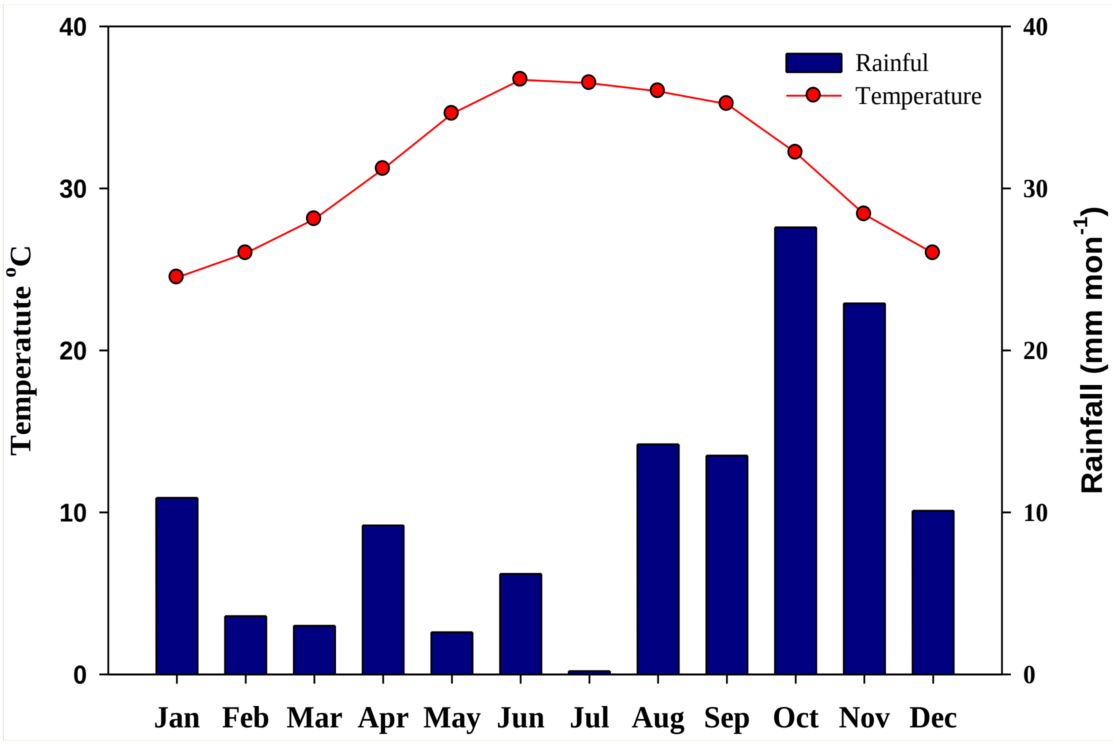

***Figure 2.** Monthly variation in the average of ambient air temperature and rainfall from 2003 to 2019 according to the data of the Meteorological Station at Makkah Al-Mukaramah (Presidency Meteorology & Environment)*

Vegetation data

One hundred and two stands were chosen to reflect the vegetation physiognomy in the Wadi Murr Al-Zahran basin in Makkah Province. These stands were distributed throughout 17 sample locations. Each stand covered an approximately 20 × 20 m area, representing the minimum vegetation area in the assessed wadi. A floristic list and quantitative estimates of floristic abundance were compiled for each stand, with calculations made for each species' mean relative density and frequency. The line intercept method was used to measure the relative species cover following Canfield (1941). According to Ludwig and Reynolds (1988), the species importance value (IV) was computed by summating the relative cover, relative density, and relative frequency. Plants' identification and nomenclature adhered to the guidelines provided by Migahid (1996), Collenette (1999), Chaudhary (1999, 2001), and Boulos (1999, 2000, 2002, 2005, 2009).

The life form spectra of the observed species were collected based on Raunkiaer (1937); meanwhile, the worldwide geographic distribution and abundance status (r: rare, rr: very rare, cc: very common, and c: common) of the documented species were compiled from Zohary (1966, 1973), Täckholm (1974), Wickens (1977), and Feinbrun-Dothan (1978, 1986). Information regarding the economic significance of the survived species was gathered through field observations, data obtained from local residents, and the literature (e.g., Mossa et al., 1987; Mandaville, 1990; Al-Yasi et al., 2019; Galal et al., 2021). Economic uses encompassed grazing, fuel, medicinal, edible, and various other purposes, like manufacturing carpets, seats, furnishings, and ornamental items.

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Soil analysis

A combined soil sample was taken at a depth of 0-50 cm from each studied stand in Wadi Murr. These samples were air-dried, sieved through a 2-mm mesh, and left for physiochemical analysis. Following the approach outlined by Allen (1989), the sieve method was used to evaluate soil grain size. The pH, electrical conductivity (EC), and Total dissolved solids (TDS) were determined in 1:5 (w/v) soil-water extracts with a 9107 BN, ORION type pH meter and a 60 Sensor Operating Instruction Corning conductivity meter. Direct titration against silver nitrate and HCl was used to measure the amounts of chlorides, carbonates, and bicarbonates, respectively. Barium chloride was used as a turbidimetric method to test sulfates. Versenate solution was used to evaluate the amounts of magnesium and calcium, while a flame photometer (Model 410) was used to estimate the amounts of sodium and potassium. These procedures were all documented in Jackson (1962) and Allen (1989).

Multivariate analysis

The matrix containing the IV of 118 species across 102 stands in Wadi Murr, Makkah, underwent analysis using TWINSPAN classification and DCA ordination (Hill, 1979 and Hill and Gauch, 1980). The relationship between the vegetation and soil variables was assessed through the PCA ordination (Kent and Coker, 1992). The alpha diversity (species richness) was evaluated as the average number of species per stand for each vegetation group, while the beta diversity (species turnover) was computed as the ratio of the number of species and species richness. The relative evenness (species equitability) was assessed using Shannon-Weaver index as $\hat{H} = -\Sigma si = 1 \text{ Pi } (\log \text{Pi})$, where Pi is the relative IV of the ith species, and S is the total number of species. Another set of heterogeneity indices included the relative dominance concentration (Simpson index), expressed as $D = 1/C$, where $C = \Sigma si = 1 \text{ (Pi)}2$, Pi is the relative species IV, and S is the total number of species (Magurran, 1988).

Statistical analysis

The association between the estimated soil variables and the dominant plant communities resulting from the TWINSPAN application was examined using Pearson correlation coefficient (r). After validating the data for variance homogeneity and normality, the variation in soil variables concerning community types was analyzed using one-way analysis of variance (ANOVA I) according to SPSS (2012).

Results

Floristic features

In the main valley of Wadi Murr, Makkah, a total of 118 plant species were documented, belonging to 81 genera and 35 families (*Table A1*). The Poaceae family was the most prevalent, with 19 species, followed by Fabaceae with 15 species, Amaranthaceae with 10 species, and Boraginaceae with 6 species (*Fig. 3*). Additionally, three families (Convolvulaceae, Asteraceae, and Zygophyllaceae) were symbolized by five species. Furthermore, only a single species each represented 15 families, which included Rutaceae, Plantaginaceae, and Urticaceae.

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Regarding life-form classification, therophytes constituted the dominant category, accounting for 38.1% of the total species, followed by chamaephytes (33.1%), hemicryptophytes (14.4%), geophytes-helophytes (7.6%), and phanerophytes (6.8%) (*Fig. 4a*). The phytogeographical distribution of the documented species showed the prevalence of bioregional taxa (47.5% of the total species) over other chorotypes, with cosmopolitan taxa having the least representation at 5.9% (*Fig. 4b*). Furthermore, based on abundance categories, 53.4% of the total species were classified as common (*Fig. 4c*). In comparison, 40.7% were categorized as rare species. Besides, three species (*Rhazya stricta*, *Flaveria trinerva*, and *Tribulus terrestris*) were very common, while four species (*Crotalaria microphylla*, *Indigofera sessiliflora*, *Corchorus depressus*, and *Eragrostis cilianensis*) were very rare.

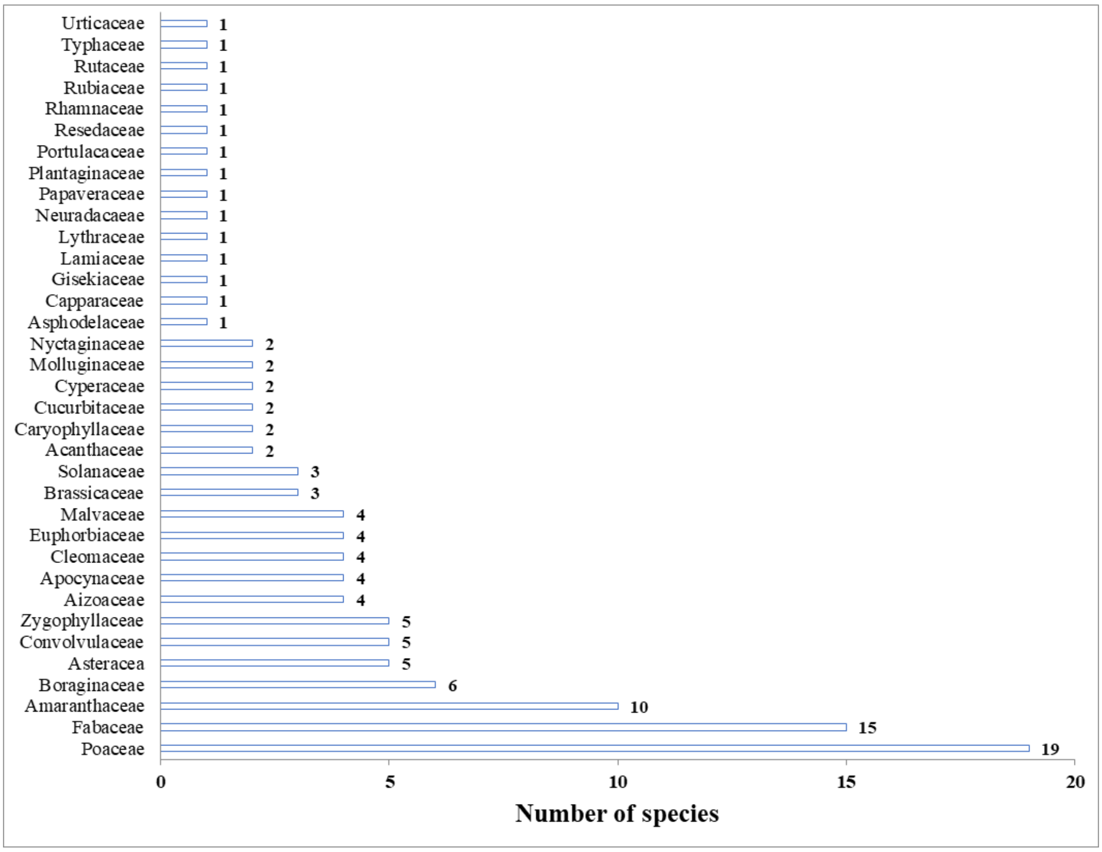

Figure 3. *Families and their relative number of species recorded in Wadi Murr, Makkah Province*

Potential economic value

According to *Figure 5*, which illustrates the economic value of the examined species in Wadi Murr, Makkah, 79.7% of the recorded species were used for grazing and browsing purposes (e.g., *Trianthema triquetra*, *Eclipta prostrata*, and *Glinus lotoides*). Additionally, 66.1% of the species were identified as medicinal plants (e.g., *Convolvulus arvensis*, *Dicliptera paniculata*, and *Rhazya stricta*), 32.2% were used for fuel (e.g., *Ocimum forskoelei*, *Aerva javanica* and *Astragalus eremophilus*), 23.7% were edible plants (e.g., *Portulaca oleracea*, *Malva parviflora*, and *Solanum nigrum*).

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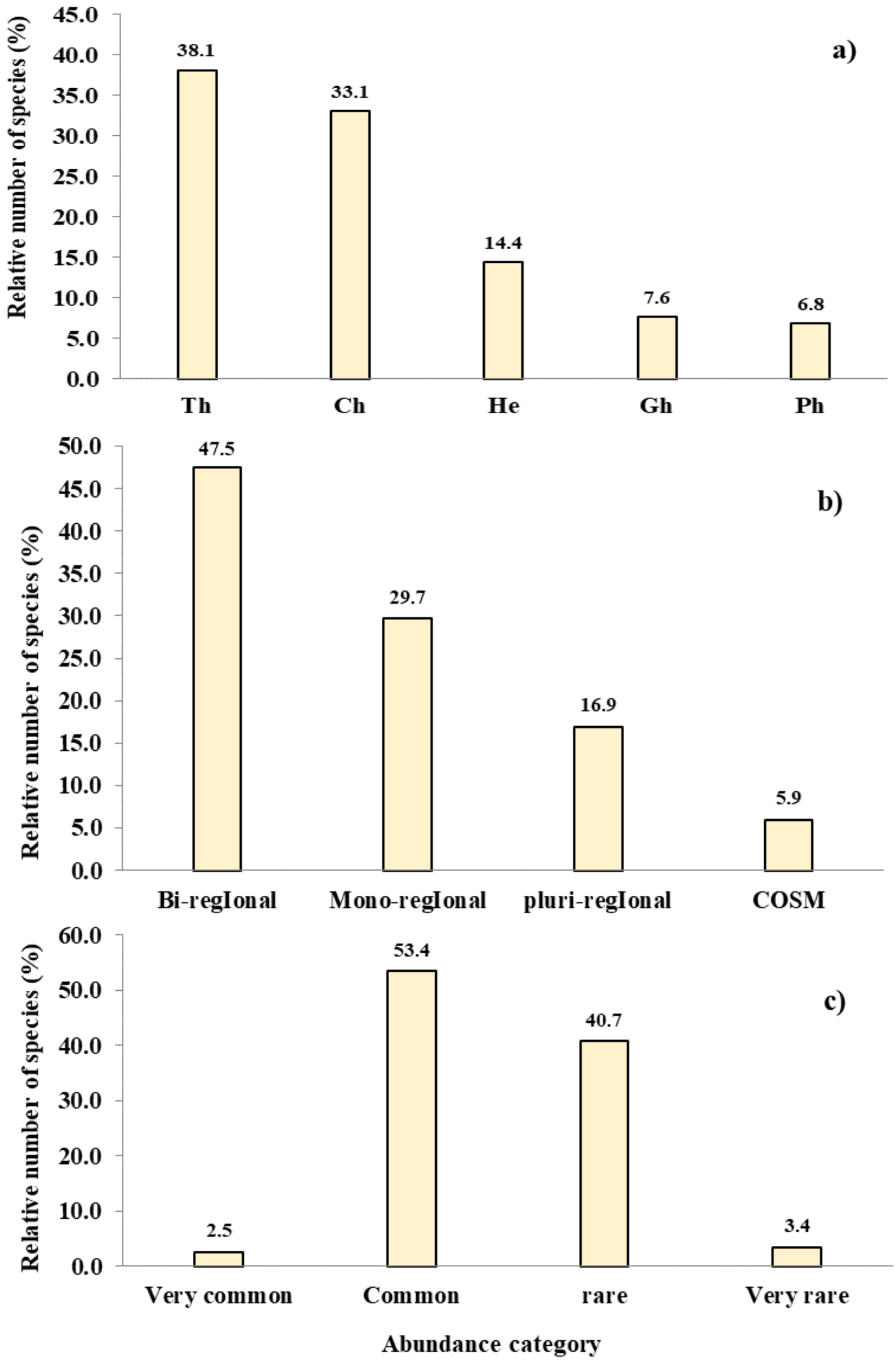

Figure 4. *Floristic characteristics of the recorded species in Wadi Al-Sharaea, Makkah Province. (a) life forms, (b) phytogeographical elements, and (c) abundance. Th: therophytes, Ch: chamaephytes, He: hemicryptophytes, Gh: geophytes, Ph: phanerophytes*

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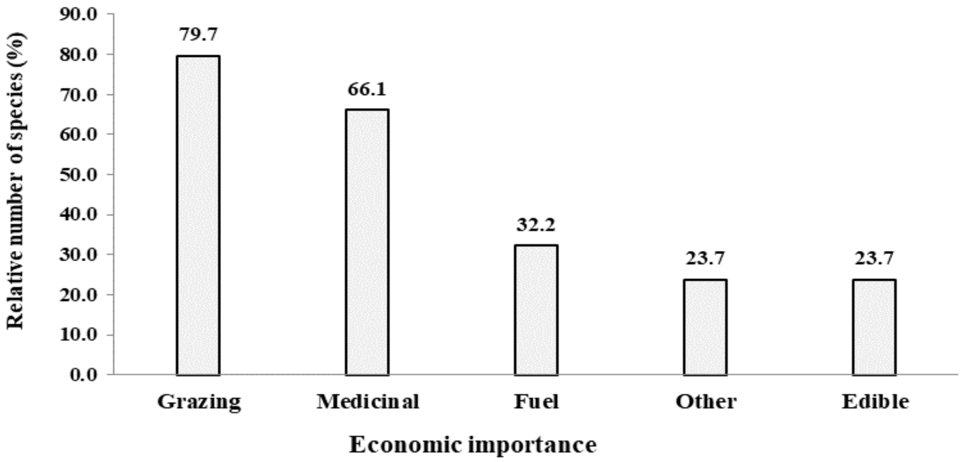

Figure 5. *Potential economic uses of the recorded species in Wadi Murr, Makkah*

Multivariate analysis

The multivariate approach assessed the important values of 118 species collected from 102 sampled stands in the Wadi Murr basin (*Table 1*). The TWINSPAN analysis identified 13 vegetation groups (VGs) clearly separated along the two DECORANA axes (*Figs. 6* and *7*). The VGs are named based on the dominant and the codominant species according to their IV. Seven VGs (D, F, H, I, K, L, M) were dominated by halophytic species of the family Zygophyllaceae. In contrast, VG (A) was dominated by the rocky community *Capparis decidua*, and VG (B and G) was dominated by the tree communities *Vachellia seyal* and *Senna italica*. Besides, VG (E) dominated by a grass community (*Aristida pennei*), and VG (J) dominated by the medicinal herb *Citrullus colocynthis*.

Table 1. *Characteristics of the 13 vegetation groups produced after applying TWINSPAN on the 102 stands in Wadi Murr, Makkah*

VG	N	G/P	1st Dominant	P (%)	IV	2nd Dominant	P (%)	IV
A	3	2.9	*Capparis decidua*	100.0	266.5	*Cenchrus divisus*	33.3	33.5
B	1	1.0	*Vachellia seyal*	100.0	76.8	*Dactyloctenium aegyptium*	100.0	62.7
C	19	18.6	*Glinus lotoides*	63.2	29.2	*Tetraena indicum*	63.2	21.0
D	13	12.7	*Tetraena indicum*	100.0	83.7	*Blepharis edulis*	76.9	21.9
E	6	5.9	*Aristida pennei*	83.3	82.9	*Rhazya stricta*	83.3	57.8
F	1	1.0	*Tribulus terrestris*	100.0	149.1	*Aizoon canariense*	100.0	37.0
G	7	6.9	*Senna italica*	85.7	26.0	*Stipagrostis hirtigluma*	71.4	37.3
H	5	4.9	*Tribulus macropterus*	100.0	47.8	*Rhazya stricta*	80.0	95.2
I	8	7.8	*Tribulus macropterus*	100.0	49.2	*Senna italica*	87.5	105.6
J	1	1.0	*Citrullus colocynthis*	100.0	95.8	*Neurada procumbens*	100.0	44.0
K	18	17.6	*Tribulus pentandrus*	100.0	51.4	*Senna italica*	88.9	40.9
L	14	13.7	*Tetraena simplex*	100.0	83.4	*Tribulus pentandrus*	92.9	83.2
M	6	5.9	*Tribulus pentandrus*	83.3	116.4	*Tetraena simplex*	83.3	26.5

V.G.: vegetation group; N: number of stands; G/P: number of stands of each group to the total number of stands; P: presence of species, IV: Importance value

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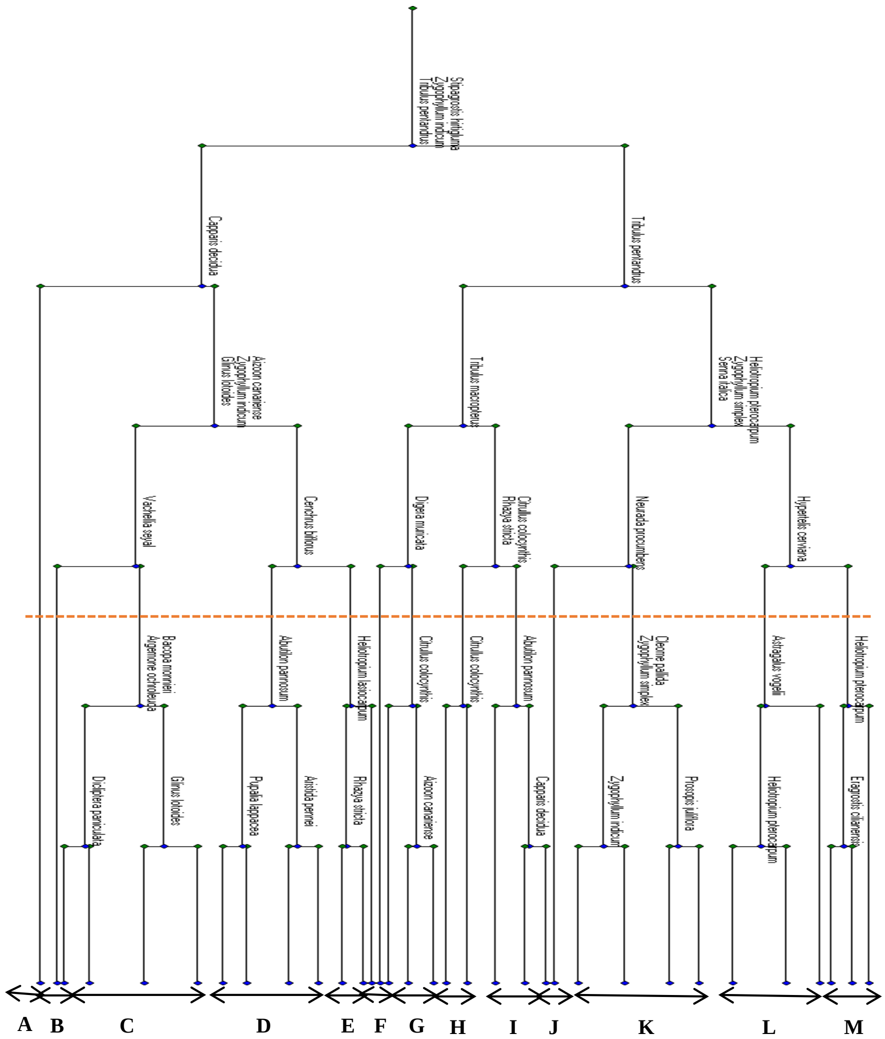

Figure 6. *The dendrogram resulting from the application of TWINSPAN on the 102 samples stands in Wadi Murr, Makkah. Indicator species of each group are indicated. The dotted red line indicates the classification level*

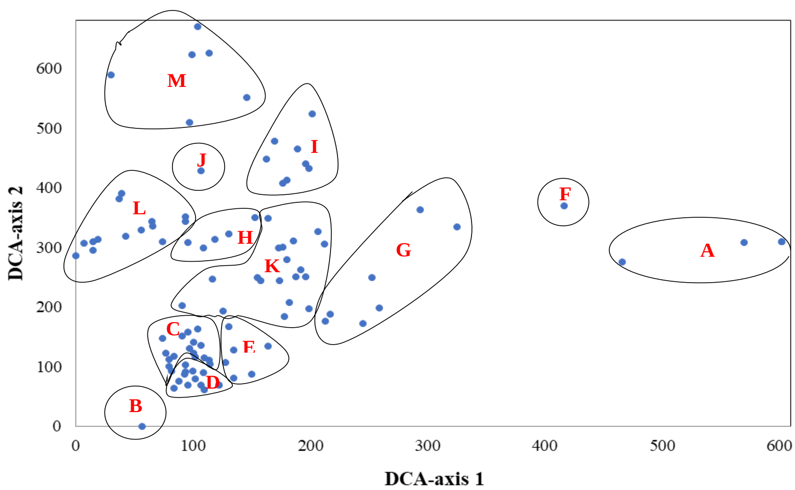

Figure 7. *DCA-ordination of the eight vegetation groups identified after the application of TWINSPAN on the 102 sampled stands in Wadi Murr, Makkah Province*

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The species diversity of the 13 VGs (*Table 2*) revealed a range of two species in *Capparis decidua-Cenchrus divisus* group (VG: A) and 67 species in *Glinus lotoides-Zygophyllum indicu*m group (VG: C). Furthermore, the *Senna italica-Stipagrostis hirtigluma* vegetation group (VG: G) exhibited the highest species richness at 13.1 species stand^{-1}, while the *Glinus lotoides-Zygophyllum indicum* group recorded the highest species turnover, equitability, and relative dominance concentration (5.9, 3.9, and 40.8, respectively). Conversely, the *Capparis decidua-Cenchrus divisus* group (VG: A) displayed the lowest species richness, equitability, and relative dominance concentration (1.3 species/stand, 0.3, and 1.2, respectively).

Table 2. *Diversity indices of the 13 vegetation groups produced after the application of TWINSPAN on the 102 stands in Wadi Murr, Makkah Province*

Diversity index	Vegetation group												
	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**
Number of species	<u>2</u>	7	<u>67</u>	35	16	11	35	18	23	8	20	19	19
Species richness	<u>1.3</u>	7.0	11.4	8.1	5.8	11.0	<u>13.1</u>	8.6	6.6	8.0	5.4	5.6	7.7
Species turnover	1.5	<u>1.0</u>	<u>5.9</u>	4.3	2.7	<u>1.0</u>	2.7	2.1	3.5	<u>1.0</u>	3.7	3.4	2.5
Relative evenness	<u>0.3</u>	1.8	<u>3.9</u>	3.2	2.5	2.4	3.4	2.8	2.8	2.1	2.5	2.5	2.7
Relative concentration of dominance	<u>1.2</u>	6.1	<u>40.8</u>	20.1	9.9	11.1	26.4	14.3	13.1	8.1	9.3	9.7	13.3

Maximum and minimum values are underlined

Soil characteristics

The mechanical and chemical soil properties showed significant variations among the 13 VGs resulted from TWINSPAN analysis (*Table 3*). According to the grain size analysis of the soil that facilitated the development of the resulting plant communities, seven vegetation groups' soils were examined (B: *Vachellia seyal-Dactyloctenium aegyptium*, C: *Glinus lotoides-Zygophyllum indicum*, G: *Senna italica-Stipagrostis hirtigluma*, I: *Tribulus macropterus-Senna italica*, K: *Tribulus pentandrus-Senna italica*, L: *Zygophyllum simplex-Tribulus pentandrus,* and M: *Tribulus pentandrus-Zygophyllum simplex*) were dominated with silt represented by 37.9, 27.5, 40.9, 55.5, 41.5, 63.4 and 47.0%, respectively (*Table 3*). In addition, four vegetation groups (D: *Zygophyllum indicum- Blepharis edulis*, E: *Aristida pennei- Rhazya stricta,* H: *Tribulus macropterus- Rhazya stricta*, and J: *Citrullus colocynthis-Neurada procumbens*) were dominated with sand (50.9, 66.2, 49.0, and 69.9%). Besides, two vegetation groups (A: *Capparis decidua-Cenchrus divisus,* and F: *Tribulus terrestris-Aizoon canariense*) were dominated by clay (38.3, and 27.6%). Conversely, investigated sites exhibit basic properties, with VG (F) Significantly having the highest pH value (8.6) and VG (E) significantly recording the lowest (7.3). VG (A) significantly exhibited the highest EC and TDS at 9.1 dS/m^2 and 5353.0 mg/l, respectively, along with the highest concentrations of CO_3^{2-}, HCO_3^-, SO_4^{2-}, and Cl^- (0.4, 2.4, 16.4, and 55.5 mg/kg).

Additionally, VG (I) significantly had the maximum level of Ca^{2+}, Mg^{2+}, Na^+, and K^+ (11.8, 3.8, 12.0, and 0.6 mg/kg, respectively). However, VG (E) significantly had the lowest pH, TDS, and SO_4^{2-} (7.3, 26.0 mg/kg, and 0.1 mg/kg, respectively), while VGs (D and E) significantly had the lowest EC, HCO_3^- and Na^+ (0.1 dS m^{-2}, 0.1 and 0.1 mg/kg), and VGs (D, F, and G) significantly had the lowest Ca^{2+} (0.2 mg/kg), Mg^{2+} (0.1 mg/kg), and Cl^- (0.2 mg/kg), respectively.

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Table 3. *Soil characteristics (means ± standard deviations) of the 13 vegetation groups in Wadi Murr, Makkah*

Soil variables		Vegetation groups													F-value
		A	B	C	D	E	F	G	H	I	J	K	L	M	
Mechanical analysis															
Gravel	%	0.3±0.1	14.3±0.3	11.8±1.6	14.6±1.0	6.9±2.0	11.1±1.0	1.7±0.4	1.3±0.3	0.1±0.0	0.3±0.0	3.4±0.7	1.3±0.4	0.4±0.1	7.4^{***}
Coarse sand	%	0.2±0.0	5.3±0.3	11.0±2.1	8.0±2.1	4.6±1.1	13.8±2.0	3.8±0.8	3.9±0.9	0.1±0.0	2.5±0.2	8.6±1.3	1.7±0.5	2.1±0.5	5.7^{***}
Fine sand	%	23.9±2.5	17.0±1.0	26.9±6.4	50.9±8.7	66.2±5.3	21.4±2.0	37.5±8.8	49.0±10.0	17.9±5.2	69.9±1.0	33.6±7.7	14.7±2.5	21.7±3.9	12.3^{***}
Silt	%	37.3±1.0	37.9±1.0	27.5±8.1	24.4±5.1	21.4±7.1	26.0±1.0	40.9±12.7	32.1±7.2	55.5±11.7	22.1±1.0	41.5±8.2	63.4±12.4	47.0±10.1	8.0^{***}
Clay	%	38.3±3.1	25.4±2.0	22.7±7.9	1.8±0.4	0.5±0.1	27.6±3.0	16.0±4.3	13.7±3.6	26.4±6.2	5.2±0.2	12.8±3.8	18.9±3.2	28.6±4.6	6.0^{***}
Soil texture		Clay loam	Silt clay loam	Silt clay loam	Sandy loam	Sandy loam	Clay loam	Silt loam	Sandy loam	Silt clay loam	Sandy loam	Silt loam	Silt loam	Silt loam	
Chemical analysis															
pH		7.8±0.4	7.8±0.2	7.7±0.4	7.3±0.2	7.3±0.1	8.6±0.4	8.0±0.1	7.7±0.1	8.2±0.6	8.1±0.4	7.9±0.4	7.8±0.3	7.9±0.1	5.2^{***}
E.C. $dS\ m^{-2}$		9.1±1.2	0.4±0.1	0.3±0.1	0.1±0.0	0.1±0.0	0.3±0.0	0.2±0.0	0.2±0.0	1.5±0.4	0.2±0.0	0.2±0.0	0.2±0.0	0.4±0.1	222.2^{***}
T.D.S. $mg\ l^{-1}$		5353.0±65.4	231.0±2.0	174.6±30.9	31.0±8.1	26.0±4.4	155.7±5.5	94.3±13.6	128.1±22.2	908.8±98.5	79.0±2.0	125.1±21.4	125.2±32.1	232.8±30.1	193.2^{***}
CO_3	$mg\ kg^{-1}$	0.4±0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1±0.0	0.0	0.0	0.0	0.0	111.2^{***}
HCO_3	$mg\ kg^{-1}$	2.4±0.4	1.2±0.2	0.8±0.3	0.1±0.0	0.1±0.0	1.3±0.3	0.9±0.3	1.2±0.1	1.6±0.2	0.8±0.2	1.1±0.1	1.0±0.2	1.3±0.2	21.6^{***}
SO_4	$mg\ kg^{-1}$	16.4±3.5	1.1±0.2	0.7±0.2	0.2±0.1	0.1±0.0	0.5±0.0	0.5±0.2	0.4±0.1	4.2±1.1	0.2±0.0	0.2±0.0	0.3±0.1	0.9±0.3	100.8^{***}
Cl	$mg\ kg^{-1}$	55.5±9.2	0.6±0.1	1.0±0.3	2.5±0.3	1.9±0.3	0.3±0.0	0.2±0.0	0.4±0.1	4.5±1.2	0.4±0.1	0.8±0.1	0.7±0.2	0.9±0.2	242.0^{***}
Ca	$mg\ kg^{-1}$	0.4±0.1	1.1±0.2	0.8±0.3	0.2±0.0	0.6±0.1	1.0±0.2	0.6±0.2	0.5±0.1	11.8±4.3	0.4±0.1	1.2±0.3	0.6±0.1	1.0±0.2	14.1^{***}
Mg	$mg\ kg^{-1}$	0.4±0.1	0.3±0.1	0.4±0.1	0.3±0.1	0.2±0.0	0.1±0.0	0.2±0.1	0.4±0.1	3.8±1.1	0.4±0.1	0.4±0.1	0.3±0.1	0.4±0.1	9.8^{***}
Na	$mg\ kg^{-1}$	0.2±0.0	0.8±0.2	0.4±0.1	0.1±0.0	0.1±0.0	0.2±0.0	0.2±0.0	0.4±0.1	12.0±3.1	0.4±0.1	0.4±0.1	0.4±0.1	0.7±0.2	21.7^{***}
K	$mg\ kg^{-1}$	0.1±0.0	0.1±0.0	0.1±0.0	0.3±0.1	0.3±0.0	0.2±0.0	0.1±0.0	0.1±0.0	0.6±0.2	0.1±0.0	0.2±0.1	0.1±0.0	0.1±0.0	4.3^{***}

The minimum and maximum values were underlined. ***: $P < 0.001$

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Soil-vegetation relationship

The Principal Component Analysis (PCA) diagram illustrated the correlation between prevalent plant communities (derived from TWINSPAN classification) and their soil characteristics (*Fig. 8*). It was observed that SO_4^{2-}, Cl^-, pH, EC, fine sand, silt, and gravel exerted a substantial influence on the dominant vegetation plant communities. *Tribulus pentandrus-Zygophyllum simplex* and *Senna italica- Stipagrostis hirtigluma* communities were significantly affected by EC. In addition, *Tribulus pentandrus-Senna italica* community was present on a high Na^+ gradient and a low fine sand gradient. Moreover, the communities dominated by *Glinus lotoides-Zygophyllum indicum* and *Vachellia seyal-Dactyloctenium aegyptium* occurred on elevated levels of Cl and lower gradients of CO_3^{2-}, HCO_3^-, and Ca^{2+}. Furthermore, *Capparis decidua-Cenchrus divisus* and *Tribulus macropterus-Senna italica* communities were significantly affected by K^+, clay, and silt, while the community dominated by *Aristida pennei- Rhazya stricta* was affected by silt. Besides, *Citrullus colocynthis-Neurada procumbens* was present on high gradients of pH and gravels and moderate gradients of TDS and coarse sand. At the same time, *Tribulus macropterus-Rhazya stricta* was present on a high gradient of SO_4^{2-}.

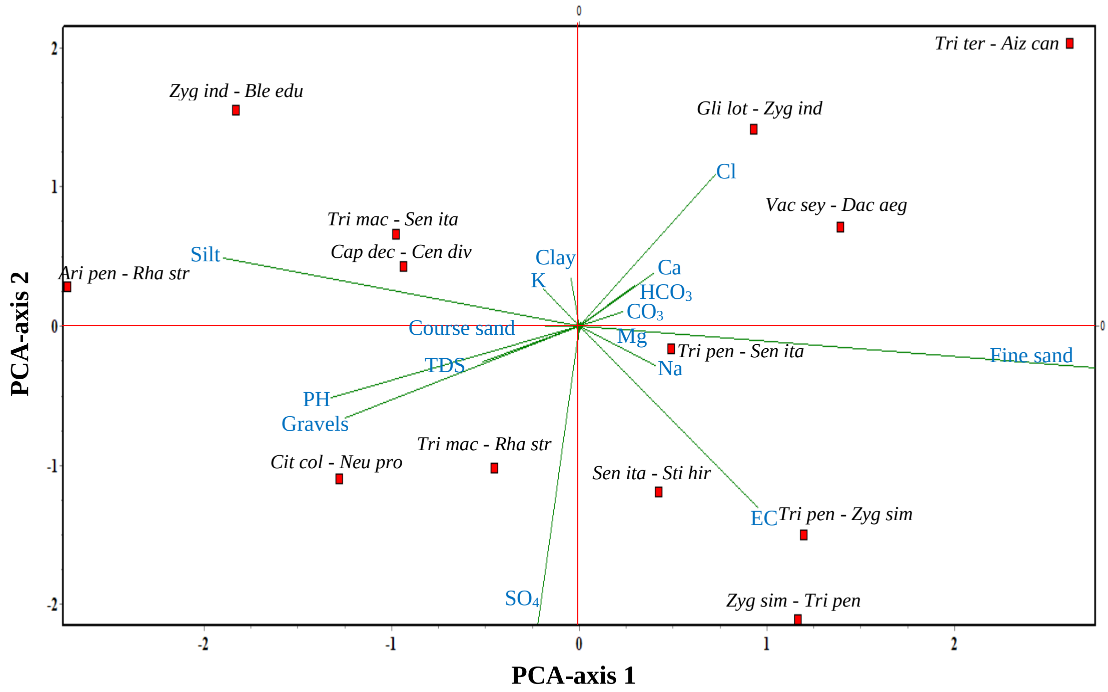

Figure 8. *PCA-ordination of the dominant plant communities along the soil in Wadi Murr, Makkah*

The simple linear correlation coefficient, examining the relationship between the IVs of the common plant communities and their corresponding soil variables (*Table 4*), revealed that certain plant communities exhibited a significant positive correlation with specific soil variables, like *Capparis decidua* with EC, TDS, Ca^{2+}, Mg^{2+}, Na^+, CO_3^{2-}, HCO_3^-, SO_4^{2-}, Cl^- and clay (r = 0.71, 0.71, 0.26, 0.26, 0.24, 0.77, 0.38, 0.71, 0.67 and 0. 26, respectively), *Senna italica* with pH, Ca^{2+}, Mg^{2+}, Na^+, K^+, HCO_3^-, SO_4^{2-}, and silt (r = 0.37, 0.45, 0.42, 0.50, 0.31, 0.39, 0.21 and 0.20), and *Tribulus macropterus* with

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pH, Ca^{2+}, Mg^{2+}, Na^{+} and HCO_3^- (r = 0.20, 0.33, 0.31, 0.45 and 0.27). Conversely, specific predominant plant communities exhibited substantial negative relationships with specific soil factors, such as *Zygophyllum indicum*, *Aristida pennei,* and *Blepharis edulis* with pH (r = -0.35, -0.25, and -0.28), HCO_3^- (r = -0.57, -0.36 and -0.45), silt (r = -0.40, -0.23 and -0.23) and clay (r = -0.34, -0.27 and -0.31), and *Tribulus pentandrus* and *Zygophyllum simplex* with gravels (r = -0.30 and -0.25), coarse sand (r = -0.24 and -0.29) and fine sand (r = -0.39 and -0.39).

Discussion

In the main valley of Wadi Murr, Makkah, there were one hundred and eighteen species of vascular vegetation belonging to 81 genera and 35 families, according to the floristic composition. This number of species approximates 64.1% of the total number of the species found in the Makkah region by Al-Eisawy and Al-Ruzayza (2015); 93.7% of total vegetation detected in Wadi Al-Noman, Makkah by Abdel Khalik et al. (2013); 99.2% of all the species found in Wadi Khulab of Jazan, Saudi Arabia by Kasem and Hamed (2017); 60.8 and 43.2% of all the species discovered in Wadi Ar'ar, southwest Saudi Arabia; and 44.4% of all the species detected in Wadi Turbah Zahran, Albaha region, southwest Saudi Arabia, according to Al-Robai et al. (2017).

The flora of Wadi Murr was notable for having a high number of species per genera (1.5 species per genus), which is approximated 1.3, 1.4, 1.5, 1.6, and 1.9 species/genus found in Wadi Turbah Zahran and Wadi Khulab (Al-Robai et al., 2017; Kasem and Hamed, 2017), Wadi Ar'ar (Osman and Abdein, 2019), Wadi Al-Noman and Wadi Al-Sharaea, Makkah (Abdel Khalik et al., 2013; Elaidarous et al., 2022), Makkah region (Al-Eisawy and Al-Ruzayza, 2015), and Taif's desert wetlands (Galal et al., 2021), respectively. Al-Nafie (2008) states low species/genera ratios are common in desert vegetation, indicating high plant diversity. Fabaceae and Poaceae are characterized by the most species (15 and 19, respectively). This conclusion is consistent with the findings published by Al-Turki and Al-Qlayan (2003), El-Ghanem et al. (2010), Farrag (2012), Alatar et al. (2012), Abdel Khalik et al. (2013), Al-Eisawy and Al-Ruzayza (2015), and Elaidarous et al. (2022). Moreover, numerous families were found to contain just one species. This may be because only a small number of these plant species are able to adapt and survive in these challenging environments; otherwise, most plant species would not be able to survive in these harsh environments (Al-Nafie, 2008; El-Ghanim et al., 2010; Al-Sherif et al., 2013; Osman and Abdein, 2019).

Topography and landforms are crucial elements in determining plant life forms (Shaltout et al., 2010; Alatar et al., 2012; Galal et al., 2021; Elaidarous et al., 2022). Therophytes and chamaephytes were the most prevalent life types in the current investigation. These results were in accordance with El-Ghanim et al. (2010), Alatar et al. (2012), Farrag (2012), Al-Sherif et al. (2013), Al-Sodany et al. (2014), Osman et al. (2014), Seraj et al. (2014) Moawed and Ansari (2015), Eisawy and Al-Ruzayza (2015), Al-Robai et al. (2017), Kasem and Hamed (2017), Al-Yasi et al. (2019), Galal et al. (2021), and Elaidarous et al. (2022). These two life forms prevail over other life forms in semi-desert and desert ecosystems due to various factors, including arid climate, topography, and biotic influence (Abdien and Osman, 2020). Additionally, Galal et al. (2021) and Alsherif (2019) observed that therophytes were the predominant life form.

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Table 4. *Simple linear correlation coefficient (r) between the dominant plant communities produced after TWINSPAN and soil variables*

Plant community/soil	pH	EC	T.D.S.	Ca	Mg	Na	K	CO_3	HCO_3	SO_4	Cl	Gravels	Course sand	Fine sand	Silt	Clay
Capparis decidua	0.06	0.71**	0.71**	0.26**	0.26**	0.24*	0.11	0.77**	0.38**	0.71**	0.67**	-0.13	-0.18	-0.10	0.02	0.26**
Vachellia seyal	-0.01	-0.02	-0.02	-0.02	-0.02	-0.01	-0.03	-0.03	0.03	-0.01	-0.03	0.11	-0.01	-0.08	-0.01	0.05
Glinus lotoides	-0.04	-0.05	-0.04	-0.05	-0.06	-0.06	-0.07	-0.07	0.09	-0.03	-0.07	-0.02	-0.06	-0.20*	0.03	0.27**
Zygophyllum indicum	-0.35**	-0.17	-0.17	-0.16	-0.12	-0.15	0.11	-0.14	-0.57**	-0.17	-0.07	0.51**	0.33**	0.35**	-0.40**	-0.34**
Aristida pennei	-0.25*	-0.09	-0.09	-0.07	-0.08	-0.08	0.15	-0.06	-0.36**	-0.09	-0.03	0.09	-0.03	0.40**	-0.23*	-0.27**
Tribulus terrestris	0.25*	-0.07	-0.07	-0.07	-0.08	-0.08	-0.03	-0.07	0.01	-0.07	-0.08	0.08	0.21*	-0.12	-0.11	0.18
Senna italic	0.37**	0.18	0.18	0.45**	0.42**	0.50**	0.31**	0.15	0.39**	0.21*	0.10	-0.27**	-0.19	-0.13	0.20*	0.12
Tribulus macropterus	0.20*	0.09	0.09	0.33**	0.31**	0.45**	0.19	0.06	0.27**	0.15	0.01	-0.21*	-0.27**	-0.11	0.16	0.16
Citrullus colocynthis	0.09	-0.08	-0.08	-0.07	-0.05	-0.07	-0.11	-0.08	0.01	-0.09	-0.08	-0.16	-0.05	0.30**	-0.11	-0.15
Tribulus pentandrus	0.15	-0.12	-0.13	-0.11	-0.11	-0.12	-0.19	-0.15	.23*	-0.16	-0.14	-0.30**	-0.24*	-0.39**	0.44**	0.19
Zygophyllum simplex	0.12	0.22*	0.23*	0.05	0.05	0.08	-0.04	0.18	0.17	0.24*	0.18	-0.25*	-0.29**	-0.39**	0.41**	0.23*
Cenchrus divisus	0.25*	0.08	0.09	0.38**	0.43**	0.21*	0.22*	0.17	0.08	0.23*	-0.05	-0.08	-0.08	-0.02	-0.03	0.14
Dactyloctenium aegyptium	-0.08	-0.04	-0.03	-0.04	-0.04	-0.03	0.10	-0.04	-0.07	-0.03	-0.03	0.11	-0.01	0.04	-0.05	-0.03
Blepharis edulis	-0.28**	-0.11	-0.11	-0.12	-0.07	-0.10	0.14	-0.08	-0.45**	-0.10	-0.02	0.36**	0.11	0.28**	-0.23*	-0.31**
Rhazya stricta	-0.07	-0.14	-0.14	-0.12	-0.12	-0.13	-0.06	-0.13	-0.15	-0.16	-0.10	-0.12	-0.19	0.11	0.05	-0.07
Aizoon canariense	0.10	-0.09	-0.08	-0.09	-0.10	-0.09	-0.05	-0.10	-0.02	-0.08	-0.10	0.29**	0.27**	-0.12	-0.22*	0.17
Stipagrostis hirtigluma	0.07	-0.13	-0.14	-0.01	-0.06	-0.09	-0.10	-0.14	0.16	-0.18	-0.13	-0.13	0.30**	0.09	0.00	-0.17
Neurada procumbens	0.08	-0.03	-0.03	-0.03	-0.02	-0.02	-0.04	-0.03	-0.03	-0.04	-0.03	-0.07	-0.05	0.20*	-0.09	-0.08

Significant values are bold

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According to Gomaa (2012), the cause could be therophytes have a short life span. Furthermore, Galal and Fahmy (2012) found that the capacity to withstand salt, sand accumulation, grazing, and drought was responsible for the large quantity of chamaephytes. Phytogeographically, the species mentioned were categorized into four groups: monoregional, bioregional, pluriregional, or cosmopolitan. Bioregional elements were the dominant taxa over the other chorotypes. Similar findings were found in the wadis of Makkah by Abdel Khalik et al. (2013), Eisawy and Al-Ruzayza (2015), and Elaidarous et al. (2022). Furthermore, inter-regional taxa including bi-, tri-, and pluri-regionals dominated the mono-regional elements in line with Galal and Fahmy (2012), who attributed their existence to the interzonal habitats (halo-, hydro-, and psammophilous sites) as well as anthropogenic effects. The majority of the species that have been observed are from Sudano-Zambezian and Saharo-Arabian components. As reported by Elaidarous et al. (2022), Galal et al. (2021), and Osman and Abdein (2019), the Saharo-Arabian elements extended southward and diminished northward, being supplanted by Mediterranean and Irano-Turanian elements. The presence of Sahara-Arabian and Sudano-Zambezian regions phytochorions indicates a dry environment with high aridity, while Mediterranean plants are suited to more moderate moisture conditions (Hamed et al., 2018; Alsherif, 2019). Additionally, based on Eisawy and Al-Ruzayza (2015) and Elaidarous et al. (2022), 53.4% of the total species were common, with 40.7% classified as rare species within the flora of Makkah Wadis.

The variability in diversity and species composition within the Wadi could be due to various factors such as altitude, precipitation, elevation gradients, slope, and topography. Thirteen vegetation groups were determined by the multivariate analysis of the species that were documented in the 102 stands. It became evident that the plant communities observed in Wadi Murr differed from those reported in Wadi Al-Noman and Wadi Al-Sharaea, Makkah (Abdel Khalik et al., 2013; Elaidarous et al., 2022); as well as, these findings were detected in other wadis in Saudi Arabia (Abd El-Ghani, 1997; Al Wadie, 2002; Alatar et al., 2012). Two plant communities (K and M) were predominated by *Tribulus pentandrus*, recognized as the dominant community in Wadi Al-Sharaea, Makkah (Elaidarous et al., 2022). Also, plant communities (H and I) were dominated by *Tribulus macropterus*.

The majority of plant communities examined in this study exhibited xerophytic characteristics, aligning with findings from several previous studies (e.g., El-Ghanem et al., 2010; Abdel Khalik et al., 2013; Al-Sodany et al., 2014; Alsherif and Fadl, 2016; Al-Yasi et al., 2019; Galal et al., 2021; Elaidarous et al., 2022) in various regions of Saudi Arabia. Furthermore, the vegetation composition across various geomorphological units highlights disparities in species richness, with values ranging from 1.3 to 13.1 species/stand, a range narrower than the 23 and 21 species/stand reported in Wadi Al-Noaman (Abdel Khalik et al., 2013) and Wadi Al-Sharaea (Elaidarous et al., 2022), respectively. Shehata and Galal (2015), Farrag (2012) proposes that fluctuations in species diversity within plant communities can be ascribed to changes in soil factors and the allelopathic effects of species on each other.

Throughout the field investigation, the authors noticed the anthropogenic and natural degradation of the native vegetation; therefore, habitat restoration is urgently necessary. The current work findings serve as a foundation for studying the vegetation-soil relationship at Wadi Murr since the soil features greatly influence the vegetation. (Gomaa, 2012). The association was explored through Principal Component Analysis (PCA) ordination. The ordination discovered that pH value, electric conductivity,

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sulphates, chlorides, fine sand, silt, and gravel significantly impacted the dominating plant communities. Besides, some plant communities (*Capparis decidua*, *Senna italic*, *Tribulus macropterus*, *Zygophyllum simplex*, and *Cenchrus divisus*) were positively affected by some soil variables (pH, EC, TDS, Ca, Mg, Na, K, CO_3, HCO_3, SO_4, Cl, clay, and silt). In contrast, others (*Zygophyllum indicum*, *Aristida pennei*, *Blepharis edulis*, *Tribulus* pentandrus, Zygophyllum *simplex*, and *Tribulus macropterus*) were negatively affected by other variables (pH, HCO_3^-, gravels, coarse sand, fine sand, silt and clay). In line with these findings, Galal et al. (2021), Hamed et al. (2018), and Farrag (2012) observed that HCO_3^-, Cl^-, and Mg^{2+} had a positive relationship with communities of xerophytes. Also, Elaidarous et al. (2022) reported that pH, HCO_3^-, K^+, Cl^-, fine sand, and clay were positively correlated with plant communities, while gravels, coarse sand, fine sand, EC, TDS, Ca^{2+}, SO_4^{-2}, and Cl^- were negatively correlated.

Numerous commercially significant plants are presently endangered or experiencing significant genetic depletion, although detailed information is lacking (Al-Yasi et al., 2019). The surviving plant species were classified in descending order according to their economic uses: grazing > medicinal > fuel > other uses > human food.

This classification was observed in studies by Elaidarous et al. (2022) conducted in Wadi Al-Sharara, Makkah; Heneidy and Bidak (2001) in Bisha, Asir region; and Al-Sodany et al. (2014) and Al-Yasi et al. (2019) in the highlands of Taif, all hypothesized a parallel pattern. Although there is little knowledge of the numerous uses of wild species, many of the substances we regularly eat are plant-based. There are still a lot of undiscovered uses for various plant species. Heneidy and Bidak (2004) claim that plants are utilized to produce a wide range of industrial goods and pharmaceuticals, the bulk of which are edible plant products that constitute the foundation of the food supply in human culture.

Conclusion

The findings of this study contribute to filling knowledge gaps regarding the flora, plant diversity, and vegetation composition of the Wadi Murr ecosystem in Makkah, Saudi Arabia. A total of 118 distinct species were identified in Wadi Murr, with therophytes being the predominant life form and biregional taxa representing the phytochorion. Thirteen community categories characterized by suitable xerophytic vegetation were delineated through phytosociological analysis. Ordination results revealed significant impacts of various soil factors, including pH value, electrical conductivity, sulphates, chlorides, fine sand, silt, and gravel, on plant communities. Moreover, certain plant communities exhibited positive responses to specific soil variables (such as pH, EC, TDS, Ca^{2+}, Mg^{2+}, Na^+, K_+, CO_3^{2+}, HCO_3^-, SO_4^{2-}, Cl^-, clay, and silt).

In contrast, others showed negative correlations with other variables (pH, HCO_3^-, gravels, coarse sand, fine sand, silt, and clay). Species richness ranged from 1.3 to 13.1 species per stand. Given the low species diversity observed in some plant communities, indicative of previous natural vegetation degradation, urgent habitat rehabilitation is recommended. Consequently, the study underscores the importance of refraining from further alterations to wadi habitats to safeguard their indigenous vegetation.

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APPENDIX

***Table A1.** Floristic features of the recorded species in Wadi Murr, Makkah Province, Saudi Arabia*

Species	Life form	Floristic categories	Economic use	A
Acanthaceae				
Blepharis edulis (Forssk.) Pers.	Ch	SA+SZ	M, G	C
Dicliptera paniculata (Forssk.) I.Darbysh.)	He	SA+SD	M	R
Aizoaceae				
Aizoon canariense L.	He	IT+ME+SA+TR	G, O	C
Trianthema portulacastrum L.	Th	SZ+TR	G	R
Trianthema triquetra Willd. ex Spreng.	Th	IT+SZ+TR	G	R
Zaleya pentandra (L.) C. Jeffrey.	He	SZ	G	R
Amaranthaceae				
Aerva javanica (Burm.f.) Juss. ex Schult.	Ch	SA+SZ+TR	M, G, F	C
Amaranthus graecizans L.	Th	PAL	M, G, E	C
Amaranthus hybridus L.	Th	TR	M, G, F, O	C
Amaranthus viridis L.	Th	COSM	M, G, E, O	C
Caroxylon villosum (Schult.) Akhani & Roalson.	Ch	ME+SA-SI + IR-TR	G, F, O	R
Chenopodiastrum murale (L.) S.Fuentes, Uotila & Borsch	Th	COSM	G, E	C
Digera muricata (L.) Mart.	Th	PAL	M, G, E, O	R
Dysphania carinata (R.Br.) Mosyakin & Clemants.	Th	ME+IR-TR	M, G, E	R
Haloxylon salicornicum (Moq.) Bunge ex Boiss.	Ch	IT+SZ	M, G, E, F, O	C
Pupalia lappacea (Mog.) Hook. f. var. velutina	Gh	SZ+TR	M, G, E, O	R
Apocynaceae				
Calotropis procera (Aiton) W.T.Aiton	Ph	SA+SZ	G, O	C
Cynanchum radians (Forssk.) Lam.	Ch	T.R.	G, E	R
Leptadenia pyrotechnica (Forssk.) Decne.	Ch	SA+SZ	M, G, F	C
Rhazya stricta Decne.	Ch	SA+SZ	M, G, O	Cc
Asphodelaceae				
Asphodelus tenufolius Cav.	Gh	IT+ME+SA	M, G, E, O	C
Asteracea				
Eclipta prostrata L.	Th	SA+SZ	G	R
Flaveria trinerva (spreng) mohr	Ch	SZ+TR	G	cc
Pulicaria guestii Rech.f. & Rawi	Ch	SA+SZ	M, O	r
Pulicaria schimperi DC.	Ch	SA+SZ	M, F, O	r
Sonchus oleraceus L.	Th	ES+IT+ME	M, G, E	r
Boraginaceae				
Heliotropium arbainense Fresen.	Ch	SA+SZ	M, F	c
Heliotropium curassavicum L.	Ch	PAN	M, F	c
Heliotropium lasiocarpum Fisch. & C.A.Mey.	Ch	SA+SZ	M, F	c
Heliotropium longiflorum (A.DC.) Jaub. & Spach	Ch	SA+SZ	M, F	r
Heliotropium pterocarpum (DC. & A.DC.) Hochst. & Steud. ex Bunge	Ch	SA+SZ	M, F	r
Trichodesma africanum (L.) Sm.	Th	SA+SZ	M, F	r
Brassicaceae				
Farsetia aegyptia Turra.	Ch	SS+SZ	M, G	c
Morettia parviflora Boiss.	Th	SZ	G	c
Schouwia purpurea (Forssk.) Schweinf.	Th	Me+SA+SZ	G	r
Capparaceae				
Capparis decidua (Forssk) Edgew	Ph	SZ+TR	M, E, F	r
Caryophyllaceae				
Polycarpaea repens (Forssk.) Asch. & Schweinf.	Ch	SA+SZ	G	c
Polycarpaea robbairea (Kuntze) Greuter & Burdet	Th	ME	G	r

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Species	Life form	Floristic categories	Economic use	A
Cleomaceae				
Cleome chrysantha Decne.	Ch	SA	M, F, O	r
Cleome pallida Kotschy.	Ch	SZ	M, G, E, F	c
Cleome paradoxa R.Br. ex DC.	He	SZ	M, G, E, F	c
Cleome scaposa DC.	Th	SA+SZ	M, G, F	r
Convolvulaceae				
Convolvulus arvensis L.	He	TR	M, G, F	c
Convolvulus cephalopodus subsp. *bushiricus* (Bornm.) J.R.I.Wood & Scotland.	Ch	S.A.	M	r
Convolvulus fatmensis Kunze.	Ch	S.A.	M	r
Convolvulus hystrix Vahl.	He	SA+SZ	M	r
Cressa cretica L.	He	ME+IT	M, F	r
Cucurbitaceae				
Citrullus colocynthis (L.) Schrad.	He	ME+SS+IT+SZ	M, G, F	c
Momordica charantia L.	Th	PT	M, G	r
Cyperaceae				
Cyperus eremicus Kukkonen	He	IR-TR	G	r
Cyperus laevigatus L.	Gh	IT+ME+SA	M, G	c
Euphorbiaceae				
*Chozophora tinctoria (*L.) A.Juss.	Gh	SZ	M, G, F	r
Euphorbia arabica Hochst. & Steud. ex T.Anderson	He	ME+SA+SZ	M	r
Euphorbia granulata Forssk	Th	SA+SZ	M	c
Euphorbia hirta L.	Th	IT+SA	M	c
Fabaceae				
Astragalus eremophilus Boiss.	Th	SA-SI	G, F, O	c
Astragalus vogelii (Webb) Bornm.	Ch	ME+SA+SZ+TR	G, O	r
Crotalaria microphylla Vahl.	Th	SA+SZ	M, G	rr
Indigofera hochstetteri Baker.	Th	SS+SZ	M, G	c
Indigofera oblongifolia Forssk.	Ch	SZ	M, O	c
Indigofera sessiliflora DC.	Th	IT+SA+TR	M, G	rr
Indigofera spinosa Forssk.	Ch	SA+SZ	M, G, F, O	c
Prosopis juliflora (Sw.) D.C.	Ph	S.A.	M, G, E, F, O	c
Senna alexandrina Mill.	Ch	SA+SZ	M, G, F, O	r
Senna italica Mill.	Ch	SA+SZ	M, G, E, F, O	c
Tephrosia nubica (Boiss.) Baker.	Ch	SA	G	r
Vachellia flava (Forssk.) Kyal. & Boatwr.	Ph	SA+SZ	M, G, F	c
Vachellia seyal (Delile) P.J.H.Hurter.	Ph	SA+SZ	M, G, F	c
Vachellia tortilis (Forssk.) Galasso & Banfi.	Ph	SZ	M, G, F, O	c
Vachellia tortilis subsp. *raddiana* (Savi) Kyal. & Boatwr.	Ph	SZ	M, G, F	c
Gisekiaceae				
Gisekia pharnaceoides L.	Th	SA+TR	M, G, E	c
Lamiaceae				
Ocimum forskoelei Benth.	He	SA	M, F	r
Lythraceae				
Ammannia auriculata Willd.	Th	S.U.	M	c
Malvaceae				
Abutilon pannosum (G.Forst.) Schltdl.	Ch	IT+SA+SZ	M, G, F	c
Corchorus depressus (L.) Peterm.	Th	ME+SA	M, G, E	rr
Malva parviflora L.	Th	IT+ME	M, G, E	c
Triumfetta flavescens Hochst. ex A.Rich.	Ch	SA+ SD	M, O	r
Molluginaceae				
Glinus lotoides L.	Th	IT+ME+TR	G	r
Hypertelis cerviana (L.) Thulin.	Th	SA+SS+SZ+TR	G	c
Neuradacaeae				

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Species	Life form	Floristic categories	Economic use	A
Neurada procumbens L.	Th	SA+SZ	G, E	r
Nyctaginaceae				
Boerhavia diffusa L.	Ch	SA+TR	M, G, E	r
Boerhavia repens L.	Ch	SA+SZ+PAN	M, G, E	r
Papaveraceae				
Argemone ochroleuca Sweet	Th	SA+SZ	M	c
Plantaginaceae				
Bacopa monnieri (L) Pennell	He	TR	G	r
Poaceae				
Aristida abnormis Chiov.	Th	SA+SZ	G	r
Aristida pennei Chiov.	Th	SA	G	c
Cenchrus biflorus Roxb.	Gh	SS+SZ	G	c
Cenchrus ciliaris L.	Gh	COSM	M, G	c
Cenchrus divisus (J.F.Gmel.) Verloove, Govaerts & Buttler.	Gh	SA+SS+SZ	G	c
Cenchrus pennisetiformis Steud.	Th	IT+SA	G	r
Cenchrus setiger Vahl	Th	PAL	G	c
Centropodia forskalii (Vahl) Cope	Gh	IT+SA	G	r
Chloris barbata Sw.	He	SZ	G	r
Dactyloctenium aegyptium (L.) Willd.	Th	TR	G	c
Echinochloa colonum (L.) Link	Th	COSM	G	c
Eleusine indica (L.) Gaertn.	Th	SZ	G	r
Eragrostis cilianensis (All.) Vignolo ex Janch.	Th	PAL	M, G, F, O	rr
Eragrostis ciliaris (L.) R.Br.	Th	SZ+TR	G, F	c
Eragrostis cylindriflora Hochst.	He	TR	G	c
Panicum turgidum Forssk	Gh	IT+ME+SZ	M, G, E, F	c
Setaria verticillata (L.) P.Beauv.	Th	COSM	G	c
Sporobolus consimilis Fresen.	He	PL	G	c
Stipagrostis hirtigluma (Steud. ex Trin. & Rupr.) De Winter	He	SA+SZ	G	r
Portulacaceae				
Portulaca oleracea L.	Th	COSM	M, G, E	c
Resedaceae				
Ochradenus baccatus Delile.	Ch	SA+SZ	M, G	c
Rhamnaceae				
Ziziphus spina-christi (L) Desf.	Ph	SA+SZ	M, G, E	c
Rubiaceae				
Kohautia caespitosa Schnizl.	Ch	IT+SA	G, O	c
Rutaceae				
Haplophyllum tuberculatum (Forssk.) A. Juss.	Ch	IT+SS	M, G, O	c
Solanaceae				
Datura innoxia Mill.	Ch	NEO+PAL	M, E, F	r
Physalis angulata L.	Th	P.A.N.	M, G, E, F, O	r
Solanum nigrum L.	Ch	COSM	M, G, E	c
Typhaceae				
Typha elephantina Roxb.	Ch	SA+IT	M, G, E, F, O	r
Urticaceae				
Forsskaolea tenacissima L.	Ch	SA+SZ	G, O	c
Zygophyllaceae				
Tribulus macropterus Boiss.	He	SZ	M, G	c
Tribulus pentandrus Forssk.	Th	SA+SZ	M, G	c
Tribulus terrestris L.	Th	ES+IT+SA+SZ	M, G	cc
Zygophyllum indicum (Burm.f.) Christenh. & Byng.	Ch	IT+SA	M, G	c
Zygophyllum simplex L.	Th	SA+SZ	M, G	c

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