

## FLORISTIC STRUCTURE AND VEGETATION DIVERSITY OF THE WADI OTHYLAN PROTECTED AREA IN SAUDI ARABIA

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**Abstract.** Wadi Othylan is one of the most important protected areas in the central region of Saudi Arabia supporting a high level of plant diversity. The current study aims to examine the vegetation and floristic diversity of wadi Othylan protected area and the relation between such diversity and soil characteristics. A total of 78 plant species belonging to 69 genera distributed among 27 families were collected from the studied stands. TWINSpan, and detrended correspondence analysis (DCA) analyses classified the plant cover data into the following four plant communities: VG I: *Fagonia bruguieri-Haloxylon salicornicum*, VG II: *Acacia ehrenbergiana-Echinops spinosissima*, VG III: *Acacia ehrenbergiana-Acacia gerardii* and VG IV: *Acacia ehrenbergiana-Calotropis procera*. Plant species present in wadi Othylan may be an indicator for the low human impact on this area. A significant variation in soil texture, pH, EC and organic matter and mineral contents were observed which was correlated with different vegetation groups.

**Keywords:** soil characteristics, TWINSpan, organic matter, pH, EC

### Introduction

Wadi Othylan is a protected area located in Al-Kharj in the central region of Saudi Arabia. The central region of Saudi Arabia is characterized by highly diverse terrain ranging from small mountains to desert plains including hillocks and plateaus (Alfarhan, 2001; Shaltout and Mady, 1996). This area belongs to the Saharo-Arabian phytogeographical zone (Alatar et al., 2012). The wadi (valley) ecosystems are considered as one of the most important plant diversity centers in the central region of Saudi Arabia; however, there has been great lack of the studies considering floristic structure and vegetation diversity of these ecosystems until now (Chaudhary, 2001; Alatar et al., 2012). Furthermore, wadi ecosystems are significant for socioeconomic development considering their ecological importance for environmental gradients and physiographic variation.

The central region of Saudi Arabia is characterized by high plant diversity; more than 600 plant species are reported in the central region out of 2,243 plant species in the whole country (Collenette, 1985, 1998, 1999; Chaudhary, 2001). Several studies have been conducted to examine the vegetation of the central region including studies concerning wadi ecosystems e.g. Wadi Al-Jufair (Alatar et al., 2012) and Wadi Hanifa (Taia and El-Ghanem, 2001; El-Ghanim et al., 2010). Other studies examined the vegetation diversity of different protected areas in Saudi Arabia including Harrat Al-Harrah (El-Sheikh et al., 2019), Huraimla (Alatar et al., 2015), and Thumamah Nature Park (El-Sheikh et al., 2013). However, the present study is the first to examine the vegetation of wadi Othylan protected area, Saudi Arabia.

The majority of soils of the natural habitats in the central region of Saudi Arabia are classified among Aridisols with very low amount or without any accumulation of organic matter and clay (Al-Nafie, 2008). On the other hand, soils in wadi basin are deep with fine texture and mixed with different sizes of rocks supporting the growth of different vegetation (Batanouny, 1987). Since wadi Othylan is one of the most important wadi habitats in the central region of Saudi Arabia and the richest wadis in vegetation and floristic diversity as it is one of the protected areas. We conducted this study aiming to examine the vegetation and floristic diversity of wadi Othylan protected area and the relation between such diversity and soil characteristics.

## Materials and methods

### *Study area*

Wadi Othylan (23°785.702'N and 46°926.531'E) is one of the most important wadis in Al-Kharj area in the central region of Saudi Arabia. It is located about 90 km southern Riyadh, the capital city of Saudi Arabia, with an altitude about 519 m above sea level with a total size of approximately 45 km<sup>2</sup> (15 km × 3 km). It is characterized by its high diverse vegetation ranged from trees to shrubs, perennials and annual plants. Wadi Othylan was considered as a protected area and national park in Saudi Arabia on 1982. The study area is considered as one of the main features of the large plateau located in the central region of Saudi Arabia known as “Najd”. This area is characterized mainly by distribution of large wadis emerging from the western mountains toward the eastern region of Najd; however, the majority of these wadis are not continuous as they covered by the sand dunes of Dahna desert. During winter rainy days, seasonal springs emerge in these wadis forming shallow pools characterized by high plant diversity. It is thought that these areas had a wetter climate in the past as remnants of their vegetation could be found along their stretch (Al-Nafie, 2008).

Plant biodiversity in wadi Othylan is significantly affected by topography factors as the area examined in this study could be separated into three different habitats i.e. depressions, rocky hills and sand dunes. Wadi Othylan is generally characterized by harsh environment; however, a great biodiversity could be found among different habitats forming the ecosystem of this wadi. In general, the dominant plant life forms during winter season are trees, shrubs and annual herbs classified mainly as mesophytes and representing different plant communities.

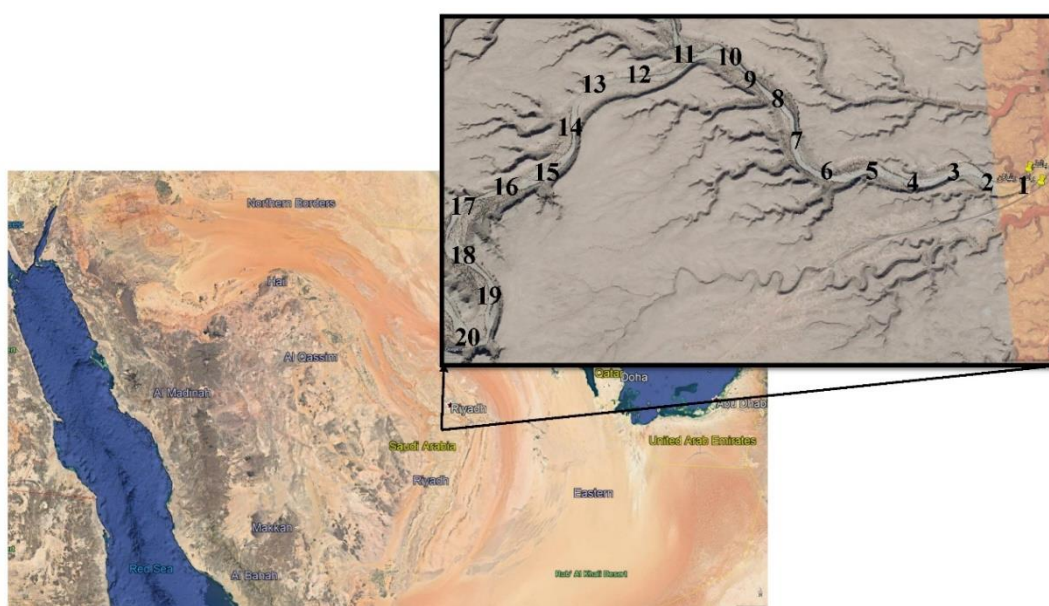
The study area could be separated into three different physiographical parts i.e. wadi bed, slope and plateau. The wadi bed (basin) is generally characterized by low sand dunes. On the other hand, plateau is dominated by shallow drainage runnels and notches due to the flat rocky surfaces with little amount of soil distributed among them. The slope is separated into top, middle and lower parts. The upper parts are very steep without any soil cover supporting only cliff vegetation. The middle parts are less steep than the upper parts covered with a mix of different sizes of rocks and shallow soil supporting vegetation different types of vegetation mainly chasmophytic shrubs and grasses. The lower parts are characterized by deep soil accumulated by run-off water and high vegetation density.

Meteorological data of the study area shows that it is characterized by hot dry weather in the summer and cold weather in the winter. Average maximum air temperature ranges from 20.3 °C in January and 44 °C in July, while the minimum air temperature ranges from 7 °C in January and 30 °C in July and August. The annual rainfall in the study area ranges from 2 to 22 mm. The mean wind speed ranges from 4 to 7 km/h. The average

relative humidity is 49% with lowest values occurs in June and July (11 – 12%). The average evaporation value is around 10.35 mm/day (Al-Nafie, 2008).

### *Sample stands*

A total of 20 study stands were selected to represent different habitats in the study site. Each stand area was 2500 m<sup>2</sup> (50 m × 50 m). *Figure 1* shows the study area with the location of the selected sample stands. Collection of samples was performed in the spring season as the majority of the species expected to exist. To analyze the vegetation of the study area, all plants collected from the different stands were identified and classified. Plant species, chorotypes and life forms (Shelter and Skog, 1978) were recorded. Identification of plant species depends mainly on the available references regarding the vegetation of Saudi Arabia (Collenette, 1985, 1998, 1999; Chaudhary, 2001). The line intercept method was used to calculate the plant cover parameters (Canfield, 1941).



**Figure 1.** Study area map showing the whole map of Saudi Arabia with focus on the study area (Wadi Othylan). The numbers on Wadi Othylan map indicate the locations of the selected sample stands

### *Soil analysis*

For soil analysis purpose, 50-cm depth soil samples were collected using soil spades from the studied stands (3 replicates each) and pooled together in one composite sample. Hydrometer method was used to examine soil texture (Allen, 1989). Mass loss after ignition at 450 °C was used as indicator for total organic matter content. An amount of 100 g of air-dried soil were suspended in 500 ml of distilled water to prepare the soil extract (1: 5). The extract was used for further chemical analysis. Soil pH and electrical conductivity (EC) was measured. Content of nutrient elements (N, P, K, Ca, Mg, Na and Fe) in the soil were analyzed using Inductively Coupled Plasma Optical Emission Spectrometry (ICP MSEOS 6000 Series, ThermoFisher Scientific) method (Allen, 1989).

## Data analysis

Multivariate analysis using TWINSPLAN software (Hill, 1979b) and detrended correspondence analysis (DCA) using DECORANA software (Hill, 1979a) were applied for the cover estimates calculated for all collected plants from the 22 studied stands. The relative cover ( $p_i$ ) of each stand was used to calculate Simpson index following the equation  $C = \sum_{i=1}^s p_i^2$  as an indicator for the relative dominance concentration and Shannon-Wiener index following the equation  $\hat{H} = -\sum_{i=1}^s p_i \log p_i$  as an indicator for the relative evenness where  $s$  is the total number of collected species (Pielou, 1975; Magurran, 1988). Pearson's simple linear correlation coefficient ( $r$ ) was used to examine the relationships among the ordination axes and the soil and community variables. The variation in the species diversity, stand traits and soil variables in relation to plant community were assessed via one-way analysis of variance using SPSS 18.0.

## Results

### Floristic structure

A total of 78 plant species belonging to 69 genera distributed in 27 families were collected from the studies stands (Appendix 1). As shown in Fig. 2, the most represented families in the study area were Compositae represented by 14 species (18%), Poaceae represented by 10 species (13%), Cruciferae represented by 7 species (9%) and Leguminosae represented by 6 species (8%). The most prominent life forms (Fig. 3a) were annual herbs (45%), perennial herbs (30%) and shrubs (22%). On the other hand, the dominant chorotypes (Fig. 3b) were the Saharo-Arabian region (49%) followed by the Saharo-Arabian-Irano-Turanian (13%) and the Sahelian-Somali-Masai (8%). Some rare species were identified e.g. *Abutilon pannosum*, *Aristida adscensionis*, and *Trigonella hamosa*. Two endangered species were identified in the study area, namely *Astragalus* sp. and *Senecio* sp.

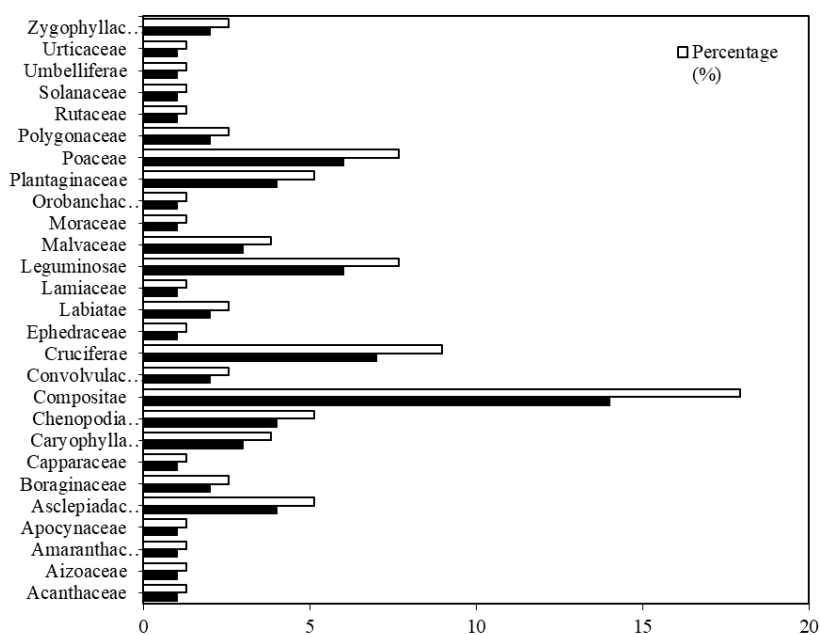
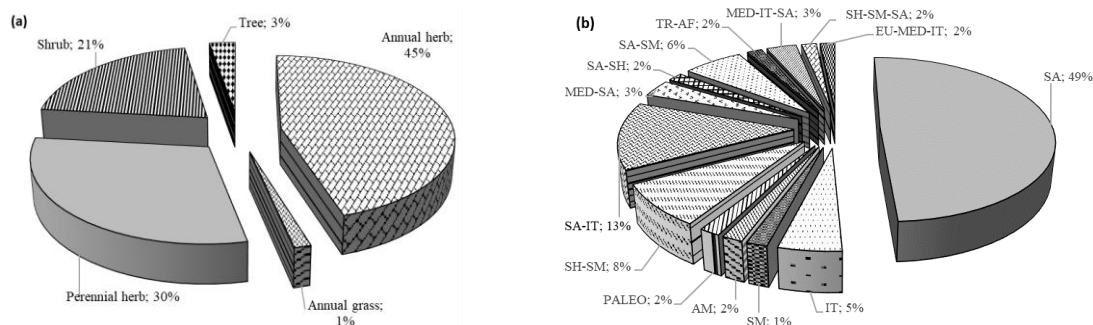


Figure 2. Families of the recorded species in Wadi Othylan



**Figure 3.** Life forms (a) and chorotypes (b) of the recorded species in Wadi Othylan (SA: Saharo-Arabian; SA-IT: Saharo-Arabian-Irano-Turanian; SH-SM: Sahelian-Somali-Masai; SA-SM: Saharo-Arabian-Somali-Masai; Med-SA: Mediterranean- Saharo-Arabian; Med-IT-SA: Mediterranean-Irano-Turanian-Saharo-Arabian; AM: American; SM: Somali-Masai; PALEO: Paleotropics; SA-SH: Saharo-Arabian- Sahelian; TR-AF: Tropical African; SH-SM-SA: Sahelian-Somali-Masai-Saharo-Arabian; EU-Med-IT: Euro-Siberian-Mediterranean-Irano-Turanian)

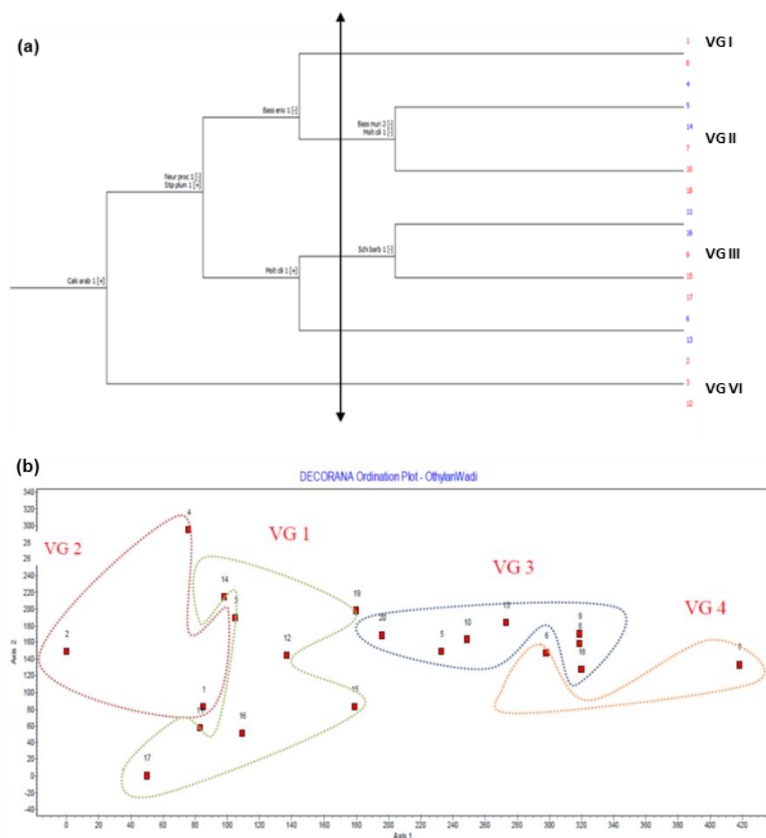
### Multivariate analysis

The dataset formed in this study consisted of 20 studied stands and 78 collected species. TWINSpan analysis of this dataset generated a dendrogram divided it into four vegetation groups (plant communities) at the second level. Characterization and nomination of these groups were assigned based on the dominant and subdominant species in each group as follows: vegetation group (VG) I: *Fagonia bruguieri*-*Haloxylon salicornicum*, VG II: *Acacia ehrenbergiana*-*Echinops spinosissima*, VG III: *Acacia ehrenbergiana*-*Acacia gerrardii* and VG IV: *Acacia ehrenbergiana*-*Calotropis procera* (Table 1). Further detrended correspondence (DCA) analysis confirmed the separation of these plant communities generated by TWINSpan and reveals a great relationship between topographic aspects and environmental gradients in Wadi Othylan (Fig. 4a,b; Appendix 1).

**Table 1.** Different vegetation groups nominated in the study site

Group	Stand No		Habitat (%)	Dominant species	P%	C%
	Stand	Total				
VG I	11,12,14, 15,16,17,19	7	A=28.5* B=43 C=28.5	<i>Haloxylon salicornicum</i>	42.86	1.57
				<i>Fagonia bruguieri</i>	71.43	2.86
				<i>Rumex vesicarius</i>	71.43	1.71
VG II	1,2,3,4	4	A=25 B=50 C=25	<i>Acacia ehrenbergiana</i>	100	6.5
				<i>Echinops spinosissima</i>	100	7.5
				<i>Farsetia longisiliqua</i>	75	5
VG III	5,8,9,10, 13,18,20	7	A=0 B=14 C=86	<i>Acacia ehrenbergiana</i>	57.14	5.71
				<i>Acacia gerrardii</i>	42.86	5.43
				<i>Plantago ovate</i>	100	12.57
VG VI	6,7	2	A=0 B=0 C=100	<i>Acacia ehrenbergiana</i>	50	3
				<i>Calotropis procera</i>	50	4.5
				<i>Schismus barbatus</i>	100	4

\*A: Terrace, B: Slope, C: Wadi bed, P: presence (%), C: cover (%)



**Figure 4.** Relationships among the four plant communities as generated by TWINSpan (a) and DECORANA (b) software. VG I: *Fagonia bruguieri*-*Haloxylon salicornicum*, VG II: *Acacia ehrenbergiana*-*Echinops spinosissima*, VG III: *Acacia ehrenbergiana*-*Acacia gerardii* and VG IV: *Acacia ehrenbergiana*-*Calotropis procera*

### Soil characteristics, plant diversity and plant community relationships

Table 2 shows that number of species was negatively correlated with pH of soil solution ( $r = -0.571$ ,  $P \leq 0.01$ ). Species richness had a negative correlation with pH of the soil solution ( $r = -0.637$ ,  $P \leq 0.01$ ); however, it was positively correlated with soil Na content ( $r = 0.461$ ,  $P \leq 0.05$ ). Similarly, Shannon index had a strong negative correlation relationship with the soil solution pH ( $r = -0.650$ ,  $P \leq 0.01$ ). On the other hand, Simpson index showed a positive correlation with pH of soil solution ( $r = 0.481$ ,  $P \leq 0.05$ ).

Table 3 shows that the *Acacia ehrenbergiana*-*Echinops spinosissima* vegetation group (VG II) had the highest number of species (21.25), species cover (73.00 m<sup>2</sup>-100 m<sup>-1</sup>) and species richness (4.72). *Fagonia bruguieri*-*Haloxylon salicornicum* vegetation group (VG I) showed the highest species evenness (0.93) with the lowest species richness (2.73). *Acacia ehrenbergiana*-*Acacia gerardii* vegetation group (VG III) showed the highest Simpson index (0.14) and the lowest species evenness (0.85). The habitats of *Acacia ehrenbergiana*-*Calotropis procera* community (VG VI) occupied the soil characterized by the highest sand content (77.00%). On the other hand, the habitats of *Fagonia bruguieri*-*Haloxylon salicornicum* community (VG I) characterized by the highest silt (24.86%) and organic matter (10.61%) contents. *Acacia ehrenbergiana*-*Echinops spinosissima* community (VG II) occupied the habitats characterized by the highest soil clay content (7.50%).

**Table 2.** Pearson correlation coefficients between species diversity and soil characteristics

Variable	No. of species	Species cover (m-100 m <sup>-1</sup> )	Species richness	Species evenness	Shannon index	Simpson index
<i>Bulk soil (%)</i>						
<b>Sand</b>	0.22	0.276	0.158	-0.374	0.103	0.26
<b>Silt</b>	-0.26	-0.326	-0.184	0.392	-0.138	-0.26
<b>Clay</b>	0.02	0.023	0.006	0.207	0.09	-0.204
<b>OM</b>	-0.244	-0.28	-0.204	0.391	-0.113	-0.22
<i>Soil</i>						
<b>pH</b>	-0.571**	-0.392	-0.637**	-0.148	-0.650**	0.481*
<b>EC (mS/cm)</b>	-0.114	-0.166	-0.083	0.214	-0.03	-0.124
<i>Mineral content (ppm)</i>						
<b>N</b>	0.011	-0.153	0.116	0.336	0.144	-0.35
<b>P</b>	-0.364	-0.308	-0.318	0.303	-0.258	-0.12
<b>K</b>	-0.183	-0.193	-0.164	0.197	-0.105	-0.077
<b>Mg</b>	-0.037	-0.145	0.017	0.227	0.057	-0.184
<b>Ca</b>	-0.043	-0.115	-0.01	0.239	0.039	-0.168
<b>Fe</b>	-0.065	-0.095	-0.05	0.198	0.006	-0.126
<b>Na</b>	0.375	0.133	0.461*	0.142	0.42	-0.315

\*: P<0.05, \*\*: P<0.01

**Table 3.** Soil variables and diversity indices of different vegetation groups in the study site. Values are shown as mean ± standard deviation

VG*	VG 1	VG 2	VG 3	VG 4	Total	F-Value
<i>Diversity indices</i>						
<b>Number</b>	9.14±1.21	21.25±4.11	14.14±5.96	17.00±1.00	14.24±5.81	8.286***
<b>Cover</b>	20.29±5.15	73.00±15.60	50.29±30.87	36.33±1.53	42.62±26.76	6.61**
<b>Richness</b>	2.73±0.35	4.72±0.78	3.43±0.97	4.45±0.23	3.59±1.02	8.67***
<b>Evenness</b>	0.93±0.06	0.92±0.03	0.85±0.08	0.91±0.00	0.90±0.07	2.76
<b>Shannon</b>	0.89±0.09	1.22±0.10	0.94±0.17	1.11±0.02	1.00±0.17	7.72**
<b>Simpson</b>	0.11±0.06	0.06±0.02	0.14±0.05	0.08±0.00	0.10±0.05	2.72
<i>Soil bulk (%)</i>						
<b>Sand</b>	68.00±11.89	74.00±8.16	71.71±9.62	77.00±13.00	71.67±10.35	0.59
<b>Silt</b>	24.86±10.38	18.50±5.74	20.86±8.40	17.00±11.00	21.19±8.91	0.71
<b>Clay</b>	7.14±1.95	7.50±2.52	7.43±1.51	6.00±2.00	7.14±1.85	0.45
<b>OM</b>	10.61±8.34	6.35±3.41	3.89±2.17	2.43±0.18	6.39±5.90	2.54
<i>Soil</i>						
<b>pH</b>	8.10±0.16	7.87±0.05	8.04±0.13	7.74±0.34	7.98±0.20	3.97*
<b>EC</b>	2.35±5.66	0.83±1.41	0.15±0.04	1.21±1.10	1.16±3.30	0.50

\* VG: vegetation group, VG I: *Fagonia bruguieri-Haloxylon salicornicum*, VG II: *Acacia ehrenbergiana-Echinops spinosissima*, VG III: *Acacia ehrenbergiana-Acacia gerardii* and VG IV: *Acacia ehrenbergiana-Calotropis procera*. \*: P<0.05, \*\*: P<0.01, \*\*\*: P<0.001

## Discussion

Topography and land forms significantly influence the growth, existence and distribution of different plant life forms in arid and semi-arid regions (Kassas and Girgis, 1964; Zohary, 1973; Shaltout et al., 2010) such the protected area of wadi Othylan; the site under study. The central region dominated mainly by the Najd plateau is characterized by the existence of different wadi (valley) habitats (Mandaville, 1990) including wadi Othylan. Wadi Othylan protected area is one of the richest wadis in vegetation and floristic diversity. The results obtained in this study indicated that the dominant life form in the study site are annual herbs (45%) and perennial herbs (30%) followed by shrubs (20.5%) and trees (2.74%). These results are comparable to the results found by El-Sheikh et al. (2019) as the annual herbs and perennials or subshrubs represented ~96% of plants identified in Harrat Al-Harrah protectorate, Northern Saudi Arabia. In another study, El-Sheikh et al. (2013) found that annual herbs and perennials dominated the identified species in Thumamah Nature Park. Like wise, perennials and annuals dominated the 128 different species identified in wadi Huraimla, Central Saudi Arabia (Alatar et al., 2015). The dominance of annual herbs could be attributed to the abundance of water during rainy seasons supporting the growth of such plants (Schulz and Whitney, 1986; Shaltout and Mady, 1996; Hosni and Hegazy, 1996; Shaltout et al., 2010). However, this water is not adequate to support the growth of perennial herbs; therefore, the existence of such plants may be due to their adaptation to the harsh conditions exist in the study site (Alatar et al., 2012).

The rarity or complete absence of synanthropic species (e.g. *Prosopis juliflora*, *Salsola imbricate*, *Tamarix nilotica*, *Bassia eriophora* and *Cynodon dactylon*) in wadi Othylan indicates low severity of human impact. Indeed, this is clearly true as wadi Othylan is considered as a protected area since more than 30 years ago. Furthermore, the presence of some rare and endangered plants in the study area is considered as another indicator for lower human impact (Taia and El-Ghanem, 2001).

The composition of vegetation life forms and chorotype in the study area showed a typical pattern of the desert flora dominated by xerophytes and chamaephytes. The same pattern of vegetation was observed in different desert habitats among different parts of Saudi Arabia (Collenette, 1985, 1998, 1999; El-Demerdash et al., 1994; Chaudhary, 2001; Al-Turki and Al-Olayan, 2003; Fahmy and Hassan, 2005; El-Ghanim et al., 2010). In either wadi or protected areas in Saudi Arabia, the previous studies showed that xerophytes and chamaephytes are the dominant life forms and chorotypes (El-Sheikh et al., 2013; Alatar et al., 2015; El-Sheikh et al., 2019). In general, there is a great correlation between the plants' life forms and topography of their habitats (Kassas and Girgis, 1964; Zohary, 1973; Shaltout et al., 2010). In this study, the dominant plant chorotype was the Saharo Arabian (49%). The species of Saharo Arabian chorotype are distributed only along the central strip of Saudi Arabia and are more abundant in habitats providing protection and/or habitats characterized by more favorable micro-climate conditions (Zohary, 1973; Hegazy et al., 1998; El-Ghanim et al., 2010; Ghazanfar and Fisher, 2013). The central region of Saudi Arabia covers a wide range of bioclimatic zones and characterized by the existence of different rocky habitats that supports several other chorotypes which were found in the study area beside the Saharo Arabian species e.g. Saharo Arabian Irano Turanian (13%) and Sahelian Somali Masai (8%). Furthermore, the Central region of Saudi Arabia covers the transition zone between the Somalia Masai zone and the Afromontane archipelago-like center (Zohary, 1973; Mandaville, 1990; White and Léonard, 1990). Some parts of the central region cover the Mediterranean and



Irano Turanian zones (Hegazy et al., 1998; Alfarhan, 1999; Ghazanfar and Osborne, 2010). Species of both zones were found in this study.

The results of correlation analysis in this study showed a positive relationship between species diversity (evenness) and soil organic matter content. In contrast, species diversity was negatively correlated with soil solution pH and EC. Other studies reported the same pattern of correlation in desert habitats of Saudi Arabia (El-Demerdash et al., 1994; Abbadi and El-Sheikh, 2002; El-Sheikh et al., 2010, 2013, 2018).

## Conclusion

The current study examined the floristic structure and vegetation diversity in the protected area of Wadi Othaylan, Saudi Arabia. The results showed that this area characterized by high plant diversity and various structure with plants classified into four different vegetation groups. Some rare and endangered plants were found in the studied area indicating the role of protection in keeping vegetation diversity. The limitation of this study were mostly relating to the high danger slopes with high number of snakes and scorpions that hinders the study of some locations, in addition to that based on the sampling areas, adding a complete list of the present species is impossible. Further studies to examine the vegetation diversity of this area and similar protected areas in Saudi Arabia are recommended.

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## APPENDIX

### Appendix I. List of collected plants and their life forms, chorotype, and coverage

Species	Life form	Chorotype*	VG I		VG II		VG III		VG IV	
			C%	P%	C%	P%	C%	P%	C%	P%
<i>Abutilon pannosum</i> <sup>1</sup>	Shrub		0.71	28.57	0.00	0.00	0.00	0.00	0.00	0.00
<i>Acacia ehrenbergiana</i>	Shrub	SH-SM	0.00	0.00	6.50	100.00	5.71	57.14	3.00	50.00
<i>Acaia gerrardii</i>	Tree	SH-SM	0.00	0.00	0.00	0.00	5.43	42.86	0.00	0.00
<i>Achillea fragrantissima</i> <sup>1</sup>	Perennial herb		0.00	0.00	2.00	75.00	0.00	0.00	0.00	0.00
<i>Aerva javanica</i> <sup>1</sup>	Perennial herb	Subshrub	0.00	0.00	1.25	50.00	0.00	0.00	0.00	0.00
<i>Aizoon canariense</i> <sup>1</sup>	Annual herb	SA	0.00	0.00	0.00	0.00	0.14	14.29	0.00	0.00
<i>Anisosciadium lanatum</i> <sup>1</sup>	Annual herb	SA	0.00	0.00	0.00	0.00	0.00	0.00	0.50	50.00
<i>Anvillea garcinia</i> <sup>1</sup>	Shrub	SA	0.00	0.00	2.00	50.00	0.00	0.00	0.00	0.00
<i>Aristida adscensionis</i> <sup>1</sup>	Perennial grass	MED-IT-SA	0.00	0.00	1.75	50.00	0.00	0.00	0.00	0.00
<i>Astragalus sp.</i> <sup>2</sup>	Annual herb	IT	0.00	0.00	0.00	0.00	0.14	14.29	0.00	0.00
<i>Bassia eriophora</i> <sup>1</sup>	Annual herb	SA-IT	0.00	0.00	0.00	0.00	0.57	42.86	0.00	0.00
<i>Bassia muricata</i>	Annual herb	SA-IT	0.00	0.00	0.00	0.00	0.29	14.29	1.00	50.00
<i>Blepharis ciliaris</i>	Herb	SA-IT	0.00	0.00	0.50	50.00	0.00	0.00	0.00	0.00
<i>Brachypodium distachyon</i>	Annual herb		0.00	0.00	0.50	25.00	0.00	0.00	1.00	50.00
<i>Calendula arvensis</i>	Annual herb		1.00	42.86	0.00	0.00	0.14	14.29	0.00	0.00
<i>Calotropis procera</i>	Shrub	SM	0.00	0.00	0.00	0.00	0.00	0.00	4.50	50.00
<i>Capparis cartilaginea</i>	Shrub		0.00	0.00	1.00	25.00	0.00	0.00	0.00	0.00
<i>Cenchrus ciliaris</i>	Perennial grass	SA	0.14	14.29	1.25	75.00	2.14	14.29	0.00	0.00
<i>Chenopodium murale</i>	Annual herb	PALEO	0.00	0.00	0.00	0.00	1.00	28.57	0.00	0.00
<i>Cistanche tubulosa</i>	Annual herb	SA-IT	0.00	0.00	0.00	0.00	0.00	0.00	0.50	50.00
<i>Convolvulus pilosellifolius</i>	Perennial herb	IT	0.00	0.00	1.00	50.00	0.00	0.00	0.00	0.00
<i>Cuscuta planiflora</i>	Annual herb	AM	0.29	14.29	1.25	75.00	1.14	42.86	0.00	0.00
<i>Diplotaxis harra</i>	Perennial herb	SH-SM	1.43	85.71	2.00	100.00	0.57	42.86	0.00	0.00
<i>Echinops spinosissima</i>	Shrub	SA	0.29	14.29	7.50	100.00	0.57	14.29	0.00	0.00
<i>Emex spinosa</i>	Annual herb	MED-SA	0.14	14.29	0.00	0.00	0.14	14.29	0.50	50.00
<i>Ephedra foliata</i>	Shrub	SH-SM	0.00	0.00	1.00	25.00	0.29	14.29	0.00	0.00
<i>Eremobium lineare</i>	Annual herb	SA	0.00	0.00	0.00	0.00	0.00	0.00	0.50	50.00
<i>Erodium laciniatum</i>	Annual herb	MED-IT-SA	0.00	0.00	0.00	0.00	0.00	0.00	0.50	50.00
<i>Fagonia bruguieri</i>	Perennial shrub	SA	2.86	71.43	3.00	50.00	2.57	85.71	0.50	50.00
<i>Farsetia longisiliqua</i>	Perennial shrub	SA	0.57	28.57	5.00	75.00	1.86	85.71	0.50	50.00
<i>Ficus palmata</i>	Tree		0.00	0.00	0.25	25.00	0.00	0.00	0.00	0.00
<i>Forsskaolea tenacissima</i>	Perennial herb		1.00	42.86	1.50	50.00	0.14	14.29	0.00	0.00
<i>Gymnocarpus decander</i>	Perennial herb	SA	0.00	0.00	0.25	25.00	0.00	0.00	0.00	0.00
<i>Haloxylon salicornicum</i>	Shrub	SA	1.57	42.86	2.50	75.00	0.57	14.29	1.50	100.00
<i>Haplophyllum tuberculatum</i>	Perennial herb	IT	0.00	0.00	0.00	0.00	0.57	28.57	0.00	0.00
<i>Heliotropium bacciferum</i>	Perennial herb	SA-SH	0.00	0.00	0.00	0.00	0.86	57.14	2.00	50.00

Species	Life form	Chorotype*	VG I		VG II		VG III		VG IV	
			C%	P%	C%	P%	C%	P%	C%	P%
<i>Hibiscus micranthus</i> <sup>1</sup>	Shrub		0.00	0.00	2.75	75.00	0.00	0.00	0.00	0.00
<i>Hyparrhenia hirta</i> 1	Perennial grass	SA	0.00	0.00	0.50	25.00	0.00	0.00	0.00	0.00
<i>Launaea angustifolia</i>	Herb	SA	0.71	42.86	1.00	50.00	0.57	28.57	0.00	0.00
<i>Launaea mucronata</i>	Annual herb	SA	0.00	0.00	0.00	0.00	0.57	42.86	0.00	0.00
<i>Leptadenia pyrotechnica</i>	Shrub	SA-SM	0.00	0.00	0.75	25.00	0.00	0.00	0.00	0.00
<i>Lycium shawii</i>	Shrub	SA	0.86	42.86	3.00	75.00	0.00	0.00	0.00	0.00
<i>Malva parviflora</i>	Annual herb	MED-SA	1.43	57.14	1.25	50.00	1.00	28.57	2.00	100.00
<i>Medicago laciniata</i>	Annual herb	SA	0.14	14.29	0.00	0.00	0.00	0.00	0.00	0.00
<i>Morettia parviflora</i>	Perennial herb	SA	0.00	0.00	0.00	0.00	0.29	14.29	0.00	0.00
<i>Notoceras bicornis</i>	Annual herb		0.00	0.00	0.00	0.00	0.29	14.29	1.00	100.00
<i>Panicum turgidum</i>	Perennial grass	SH-SM-SA	0.00	0.00	0.50	25.00	0.00	0.00	0.50	50.00
<i>Pennisetum divisum</i>	Perennial grass	SA	0.00	0.00	2.00	25.00	0.00	0.00	0.00	0.00
<i>Pergularia tomentosa</i>	Perennial herb	SA	0.00	0.00	0.00	0.00	0.14	14.29	0.00	0.00
<i>Periploca aphylla</i>	Shrub	TR-AF	0.00	0.00	3.00	50.00	0.00	0.00	0.00	0.00
<i>Picris babylonica</i>	Annual herb	SA	0.00	0.00	0.00	0.00	1.14	57.14	0.00	0.00
<i>Plantago amplexicaulis</i>	Annual herb	SA	0.71	28.57	0.00	0.00	0.00	0.00	0.00	0.00
<i>Plantago boissieri</i>	Annual herb	SA	0.00	0.00	0.00	0.00	0.57	14.29	0.50	50.00
<i>Plantago ciliata</i>	Annual herb	SA	0.00	0.00	0.00	0.00	0.57	28.57	0.50	50.00
<i>Plantago ovata</i>	Annual herb	SA-IT	0.00	0.00	0.25	25.00	12.57	100.00	3.00	50.00
<i>Pulicaria glutinosa</i>	Shrub	SA-IT	0.00	0.00	1.50	50.00	0.29	14.29	0.00	0.00
<i>Pulicaria undulata</i>	Shrub	SA-SM	0.00	0.00	0.50	25.00	0.00	0.00	1.00	50.00
<i>Reichardia tingitana</i>	Annual herb		0.00	0.00	0.25	25.00	0.00	0.00	0.00	0.00
<i>Rhanterium epapposum</i>	Perennial herb	SA	0.00	0.00	1.50	25.00	0.00	0.00	0.00	0.00
<i>Rhazya stricta</i>	Perennial herb	SA	0.00	0.00	0.00	0.00	0.71	42.86	1.50	50.00
<i>Rumex vesicarius</i>	Annual herb	SA	1.71	71.43	4.50	100.00	0.86	57.14	0.00	0.00
<i>Salvia aegyptiaca</i>	Perennial herb		0.29	14.29	0.00	0.00	0.14	14.29	0.00	0.00
<i>Salvia deserti</i>	Perennial herb	SA	0.00	0.00	1.25	50.00	0.00	0.00	0.00	0.00
<i>Savignya parviflora</i>	Annual herb	SA	0.57	42.86	0.00	0.00	0.71	42.86	1.50	100.00
<i>Schismus barbatus</i>	Annual grass	SA-IT	0.00	0.00	0.00	0.00	0.00	0.00	4.00	100.00
<i>Sclerocephalus arabicus</i>	Perennial herb	SA	0.57	14.29	0.00	0.00	0.14	14.29	0.00	0.00
<i>Senecio flavus</i>	Annual herb		1.14	71.43	2.00	50.00	0.29	28.57	0.50	50.00
<i>Senecio sp.</i> <sup>2</sup>	Annual herb		0.00	0.00	1.25	25.00	0.00	0.00	0.00	0.00
<i>Senna italica</i>	Shrub	SH-SM	0.14	14.29	0.00	0.00	0.14	14.29	0.00	0.00
<i>Sisymbrium irio</i>	Annual herb		0.57	42.86	1.25	75.00	1.71	71.43	1.00	50.00
<i>Spergula fallax</i>	Annual herb		0.00	0.00	0.00	0.00	0.14	14.29	2.00	100.00
<i>Stipa capensis</i>	Annual herb	SA-SM	0.43	28.57	0.25	25.00	0.43	14.29	0.50	50.00
<i>Tetrapogon villosus</i>	Perennial herb	SA-IT	0.00	0.00	0.50	25.00	0.29	14.29	0.00	0.00
<i>Teucrium polium</i>	Perennial herb	SA-IT	0.00	0.00	0.00	0.00	0.43	14.29	0.00	0.00
<i>Tribulus terrestris</i>	Annual herb	EU-MED-IT	0.14	14.29	0.00	0.00	0.14	14.29	0.00	0.00
<i>Trichodesma africanum</i>	Perennial herb	SA	0.86	14.29	1.25	75.00	0.14	14.29	0.00	0.00
<i>Trigonella hamosa</i> <sup>1</sup>	Annual herb	SA	0.00	0.00	0.00	0.00	0.00	0.00	0.50	50.00
<i>Tripleurospermum auriculatum</i>	Annual herb	SA-SM	0.00	0.00	0.00	0.00	1.14	28.57	0.00	0.00

<sup>1</sup> rare species, <sup>2</sup> endangered species, \*SA: Saharo-Arabian; SA-IT: Saharo-Arabian-Irano-Turanian; SH-SM: Sahelian-Somali-Masai; SA-SM: Saharo-Arabian-Somali-Masai; Med-SA: Mediterranean- Saharo-Arabian; Med-IT-SA: Mediterranean-Irano-Turanian-Saharo-Arabian; AM: American; SM: Somali-Masai; PALEO: Paleotropics; SA-SH: Saharo-Arabian- Sahelian; TR-AF: Tropical African; SH-SM-SA: Sahelian-Somali-Masai-Saharo-Arabian; EU-Med-IT: Euro-Siberian-Mediterranean-Irano-Turanian