

## Vegetation and soil relationships in the inland wadi ecosystem of central Eastern Desert, Egypt

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**Abstract:** In January 2010, torrential rains that had suddenly swept away a limited area in the Eastern Desert facing Qena Province in Upper Egypt resulted in the enriching of the vegetation of some extremely dry wadis at this location. A vegetation survey carried out shortly after this event, in April, revealed the prevalence of annuals in considerable abundance, which are hardly recognisable in such usually dry habitats. The normally scarce perennial vegetation had flourished, too. A total of 32 species, 11 annuals, and 21 perennials that belong to 27 genera and 15 families were recorded. The life-form spectrum in the present study is characteristic of an arid desert region with the dominance of chamaephytes (31% of the recorded species) and therophytes (28%), followed by hemicryptophytes and phanerophytes (19% for each). Phytogeographically, the Saharo-Arabian element forms the major component of the floristic structure. The investigation revealed that the wadis studied are potential shelters of 4 vegetation groups. Detrended correspondence analysis represented the distribution of the 4 vegetation groups along the first 2 axes. Canonical correspondence analysis indicated that the distribution of vegetation in the study area was mainly controlled by gravel, pH,  $\text{SO}_4^{-2}$ , chlorides,  $\text{K}^+$ ,  $\text{Mg}^{+2}$ , and total soluble salts.

**Key words:** Egypt, soil-vegetation relationships, multivariate analysis, desert wadis

### 1. Introduction

The Eastern Desert of Egypt occupies the area extending from the Nile Valley eastward to the Gulf of Suez and the Red Sea, which is about 223,000 km<sup>2</sup>, i.e. 22.3% of the total area of Egypt. It is traversed by numerous canyon-like depressions (wadis) running to the Red Sea or to the Nile Valley. It consists of a high backbone of high rugged mountains that run parallel to and at a relatively short distance from the coast. These mountains are flanked to the north and west by an intensively dissected sedimentary plateau (Said, 1962).

From the early beginnings of the last century, the Eastern Desert was studied botanically by different scholars (e.g., Schweinfurth, 1901; Montasir, 1938; Hassib, 1951; Girgis, 1965; Kassas, 1953a, 1953b, 1953c, 1955, 1966, 1971; Kassas & El-Abyad, 1962; Kassas & Girgis, 1964, 1970, 1972; Hassan, 1987; Salama & Fayed, 1989, 1990; Salama & El-Naggar, 1991; Abd El-Ghani, 1998; Hassan, 2003). Except for that of Hassan (1987), most of the previous studies dealt with the different ecological aspects, with less attention to the floristic features of this desert.

The inland desert wadis, particularly those that intersect the Eastern Desert, differ greatly in their water resources. The wadis in this study presented a lack of such resources and therefore belong to extremely dry habitats among similar wadis that drain this desert into the Nile Valley on rare occasions when rainfall occurs. Such rains usually happen in sudden torrents that overflow in wadi courses that usually originate in mountainous areas in the middle of this desert and flow eastward or westward to the Red Sea or Nile Valley, respectively. In January 2010, torrential rains that had suddenly swept the general area of Qena-Luxor, where these wadis extend (Figure 1), resulted in enriched vegetation of some extremely dry wadis at this location. This leads to the prevalence of annuals and the flourishing of the scarce perennial vegetation (El-Sharkawi et al., 1982a, 1982b). Such an event was the inspiration to carry out this study with the aim of recognising the potential of natural vegetation in the wadis as a result of an unexpected water supply. The relationships between the soil and its associated vegetation were investigated.

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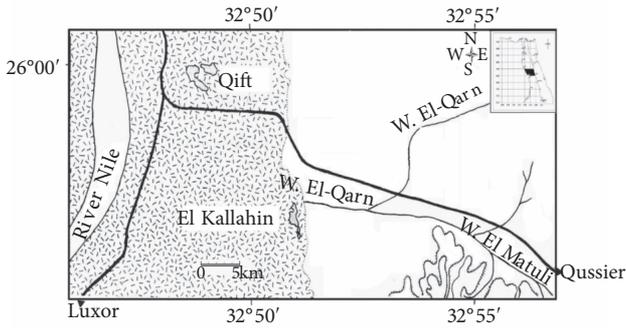


Figure 1. Location map of the study area.

## 2. Materials and methods

Wadi El-Matuli (25°55'N–26°00'N, 32°50'E–33°00'E) is a tributary of Wadi El-Qarn, and the latter comprises the deltaic part (Figure 1). Both wadis proliferate in an area that extends about 45 km east of the Nile Valley in the vicinity of the town of Qift in Upper Egypt. In their extension, the 2 wadis are rather wide (2 km wide in some parts), with a flat floor, which is mostly exposed to solar radiation during the day and is without microhabitat shelters for shade plants. The floor of the wadi is only 86 m above sea level as indicated by GPS. The plateau around is about 134 m above sea level. Meteorological data obtained from the South Valley University station at Qena showed on average that the maximum summer temperature was

40.9 °C and the minimum temperature was 25.1 °C. The coldest winter month maximum temperature was 23.3 °C and the minimum temperature was 8 °C. Relative humidity ranges from 45.9% in winter to 17.1% in summer. Rains occur only in May with 0.5 mm.

The geology of the area has been described by Barron and Hume (1902) and Said (1962). The 2 wadis dissect a sedimentary plateau in which the sediments range in age from late Cretaceous up to recent sediments. A succession of variegated shales bound the southern part of the valley from the late Cretaceous to early Eocene. The northern side of the valley is bound by a relatively lower escarpment composed of sandstone conglomerates and shales mainly from the Pliocene/Plio-Pleistocene terraces, and alluvial fans that cover parts of the deltaic area. The valley floor is covered by recent sediments composed of various size formations ranging from igneous and metamorphic cobbles eroded from the Red Sea basement ridge, some 100 km to the east, to clay particles from sedimentary rocks that border the valley.

The fieldwork was conducted from April 2010 to November 2011 during several trips. The wadis under consideration are easily traversable by appropriately equipped vehicles. The locations (stands) studied were randomly chosen whenever considerable vegetation cover was encountered. In general, dense vegetation was found across the wadis (Figure 2). In analysing vegetation of stands, multivariate analysis was adopted. Thirty-two stands were found to be satisfactory to represent the

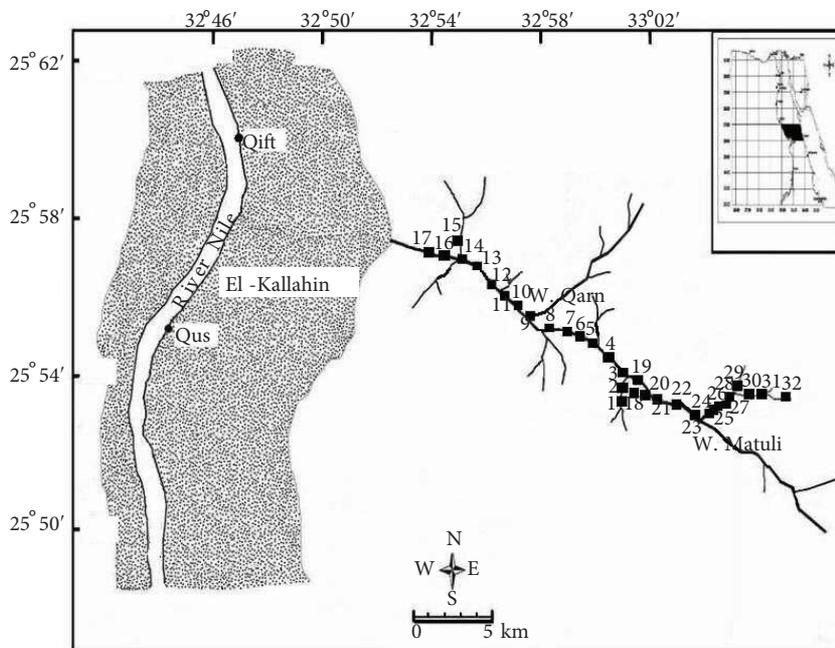


Figure 2. Distribution of the studied stands in the study area.

vegetation of the area. Based on the presence/absence of each species, 32 stands were studied along the main trunk of the 2 wadis and georeferenced using GPS techniques (Figure 2).

Plant specimens collected were identified and deposited at the herbarium of the Botany Department of Assiut University. Identifications were done according to Täckholm (1974) and Boulos (1995, 1999, 2000). Duplicates were checked for identification and deposited at the Cairo University Herbarium.

For each sampled stand, 3 soil samples were collected from profiles of 0–50 cm in depth. These samples were then pooled together to form one composite sample, air-dried, and thoroughly mixed. Textures were determined using the hydrometer method, providing quantitative data on the percentage of sand, silt, and clay. Organic matter content and soil water content were estimated by drying and then ignition at 600 °C for 3 h. Soil–water extracts (1:5) were prepared for the determination of electric conductivity and pH. Determination of calcium and magnesium were carried out by titration methods with 0.01 N EDTA (Upadhyay & Sharma, 2005). Sodium and potassium were determined using the flame photometer technique (Jackson, 1967). Available phosphorus was determined calorimetrically by the ascorbic acid method (Watanabe & Olsen, 1965). Available potassium was determined by flame photometer according to Soltanpour (1985). Estimation of chlorides was carried out by titration methods using 0.005 N silver nitrate (Kolthoff & Stenger, 1974; Hazen, 1989).

In order to obtain an effective analysis of the vegetation and related environmental factors, both classification and ordination techniques were employed. A floristic data matrix of 32 stands and 32 species was subjected to classification by cluster analysis with the computer program MVSP, version 3.1 (Kovach, 1999), using squared Euclidean distance dissimilarity matrix with minimum variance (also called Ward's method) as the agglomeration criterion (Orlóci, 1978). The computer program CANOCO, version 4.5 (ter Braak, 2003), was used for all ordination analyses, and SPSS 10.0 (SPSS, 1999) was used for all statistical treatments. Detrended correspondence analysis (DCA), an indirect gradient analysis technique, was used to identify the main gradients that influence species distribution. Preliminary analyses were made by applying the default option of DCA (Hill & Gauch, 1980) to check the magnitude of change in species composition along the first axis (i.e. gradient length in standard deviation [SD] units). In the present study, DCA estimated the compositional gradient in the vegetation data to be larger than 4.0 SD units for the first axis; thus, canonical correspondence analysis (CCA) was the appropriate ordination method to perform direct gradient

analysis (ter Braak, 2003). Principal coordinates analysis was used as an ordination method. CCA was performed using 13 environmental variables after exclusion of electric conductivity, sodium, coarse sand, and fine sand due to their high inflation factors. All the default settings were used for CCA, and a Monte Carlo permutation test (499 permutations; ter Braak, 1994) was used to test for significance of the eigenvalues of the first canonical axis. Intraset correlations from the CCAs were used to assess the importance of the environmental variables.

### 3. Results

#### 3.1. Floristic analysis

A total of 32 species (11 annuals and 21 perennials) belonging to 27 genera and 15 families were recorded (Table 1). The largest families were Zygophyllaceae (7); Asteraceae and Boraginaceae (4 for each); Papilionaceae (3); and Asclepiadaceae, Chenopodiaceae, and Tamaricaceae (2 for each). They constituted about 75% of the recorded flora and represent most of the floristic structure in the Eastern Desert. Seven families were represented by only 1 species. The largest genus was *Fagonia* (4 species).

Four of the recorded species are ubiquitous (have a wide ecological range of distribution), viz. *Salsola imbricata* subsp. *imbricata*, *Schouwia purpurea*, *Zygophyllum coccineum*, and *Zilla spinosa* with the highest presence values (96.88%, 93.75%, 93.75%, and 84.38%, respectively). On the other hand, *Launaea cassiniana*, *Zygophyllum simplex*, *Tamarix nilotica*, and *Cotula cinerea* showed the highest presence estimates amongst annuals (68.75%, 68.75%, 53.13%, and 40.63%, respectively). Twenty-one species, or about 65.63% of the total recorded species, are perennials and demonstrated a certain degree of constancy. The presence of *Tamarix aphylla*, *T. nilotica*, and *Salsola imbricata* subsp. *imbricata* refers to salinisation.

#### 3.2. Biological spectrum

Figure 3 shows the life forms of the recorded species according to the Raunkiaer system (1937). Six life forms were recognised, of which chamaephytes (31.25%) constitute the largest number of species (10 species) and therophytes (9 species) ranked second with 28.13%. Phanerophytes and hemicryptophytes (6 species for each) represent about 37.5% of the total flora. Geophytes (3.13%) are represented by 1 species.

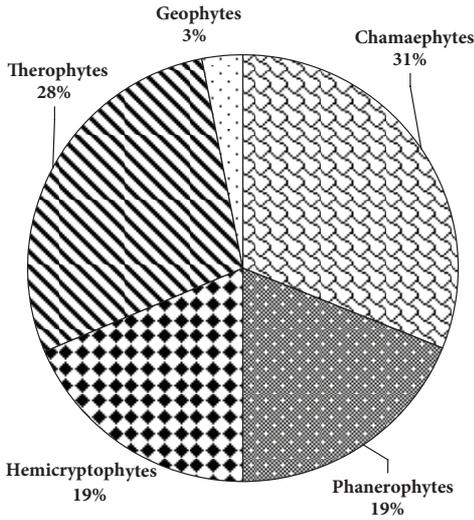
#### 3.3. Chorological affinities

Results of the total chorological analysis of the surveyed flora, presented in Figure 4, revealed that 16 species (50% of the total flora) are monoregional, of which 15 species (46.9%) are native to the Saharo-Arabian chorotype. Sudano-Zambezian ranked second with 3.1%. About 46.9% of the recorded species are biregional and pluriregional, extending their distribution all over the Saharo-Arabian,

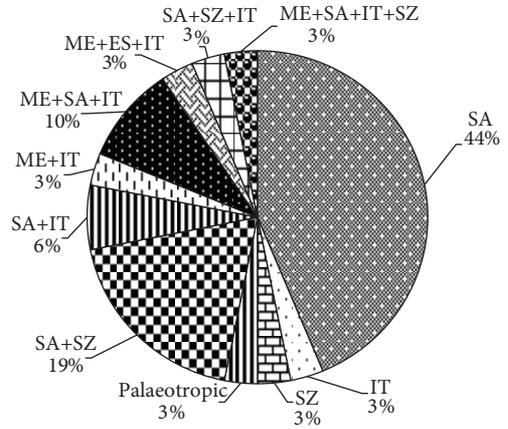
**Table 1.** Floristic composition, presence value, life forms, and chorology of the recorded species in the studied area of wadi El-Matuli and wadi El-Qarn in the Eastern Desert of Egypt.

Species	Duration	Chorology	LF	P%
<b>Amaranthaceae</b>				
<i>Amaranthus graecizans</i> L.	Per.	ME+IT	Ch	3.13
<b>Asclepiadaceae</b>				
<i>Calotropis procera</i> (Aiton) W.T.Aiton	Per.	SA+SZ	Ph	6.25
<i>Leptadenia pyrotechnica</i> (Forssk.) Decne.	Per.	SA+SZ	Ph	9.38
<b>Asteraceae</b>				
<i>Cotula cinerea</i> Delile	Ann.	SA	Th	40.63
<i>Launaea cassiniana</i> (Boiss.) Kuntze	Ann.	SA	Th	68.75
<i>Pergularia tomentosa</i> L.	Per.	SA+SZ	Ch	3.13
<i>Pulicaria undulata</i> (L.) C.A.Mey.	Per.	SA	H	9.38
<b>Boraginaceae</b>				
<i>Trichodesma africanum</i> (L.) R.Br.	Ann.	SA+SZ	Ch	18.75
<i>Morettia philaeana</i> (Delile) DC.	Ann.	SA	H	12.50
<i>Schouwia purpurea</i> (Forssk.) Schweinf.	Ann.	SA	Th	93.75
<i>Zilla spinosa</i> (L.) Prantl.	Per.	SA	Ch	84.38
<b>Brassicaceae</b>				
<i>Diplotaxis acris</i> (Forssk.) Boiss.	Ann.	SA	Th	9.38
<b>Chenopodiaceae</b>				
<i>Haloxylon salicornicum</i> (Moq.) Bunge ex Boiss.	Per.	SA+IT	Ch	21.88
<i>Salsola imbricata</i> Forssk. subsp. <i>imbricata</i>	Per.	SA	Ch	96.88
<b>Cucurbitaceae</b>				
<i>Citrullus colocynthis</i> (L.) Schrad.	Per.	ME+SA+IT	H	12.50
<b>Malvaceae</b>				
<i>Malva parviflora</i> L.	Ann.	ME+ES+IT	Th	15.63
<b>Mimosaceae</b>				
<i>Acacia tortilis</i> (Forssk.) Hayne subsp. <i>raddiana</i> (Savi) Brenan	Per.	SA	Ph	6.25
<b>Papilionaceae</b>				
<i>Astragalus hamosus</i> L.	Per.	ME+IT	Th	9.38
<i>Crotalaria aegyptiaca</i> Benth.	Per.	SZ	H	3.13
<i>Lotus hebranicus</i> Brand	Ann.	SA	H	6.25
<b>Poaceae</b>				
<i>Phragmites australis</i> (Cav.) Trin. ex Steud.	Per.	PAL	G	6.25
<b>Polygonaceae</b>				
<i>Rumex vesicarius</i> L.	Ann.	ME+SA+IT	Th	21.88
<b>Rhamnaceae</b>				
<i>Zizyphus spina-christi</i> (L.) Desf.	Per.	ME+SA+IT+SZ	Ph	12.50
<b>Tamaricaceae</b>				
<i>Tamarix aphylla</i> (L.) H.Karst.	Per.	SA+SZ+IT	Ph	15.63
<i>T. nilotica</i> (Ehreub.) Bunge	Per.	ME+SA+ IT	Ph	53.13
<b>Zygophyllaceae</b>				
<i>Fagonia Arabica</i> L.	Per.	SA	Ch	34.38
<i>F. bruguieri</i> DC.	Per.	SA+IT	H	3.13
<i>F. indica</i> Burm.	Per.	SA	Ch	3.13
<i>F. thebaica</i> Bioss.	Per.	SA	Ch	3.13
<i>Tribulus pentandrus</i> Forssk.	Ann.	SA+SZ	Th	12.50
<i>Zygophyllum coccineum</i> L.	Per.	SA	Ch	93.75
<i>Z. simplex</i> L.	Ann.	SA+SZ	Th	68.75

**Abbreviations:** P% = presence values, Per. = perennials, Ann. = annuals, LF = life form, Ph = phanerophyte, H = hemicryptophyte, Ch = chamaephyte, Th = therophyte, G = geophyte, SA = Saharo-Arabian, SZ = Sudano-Zambeian, IT = Irano-Turanian, ES = Euro-Siberian, ME = Mediterranean, PAL = Palaeotropical.



**Figure 3.** Life-form spectrum of the recorded species in the study area.

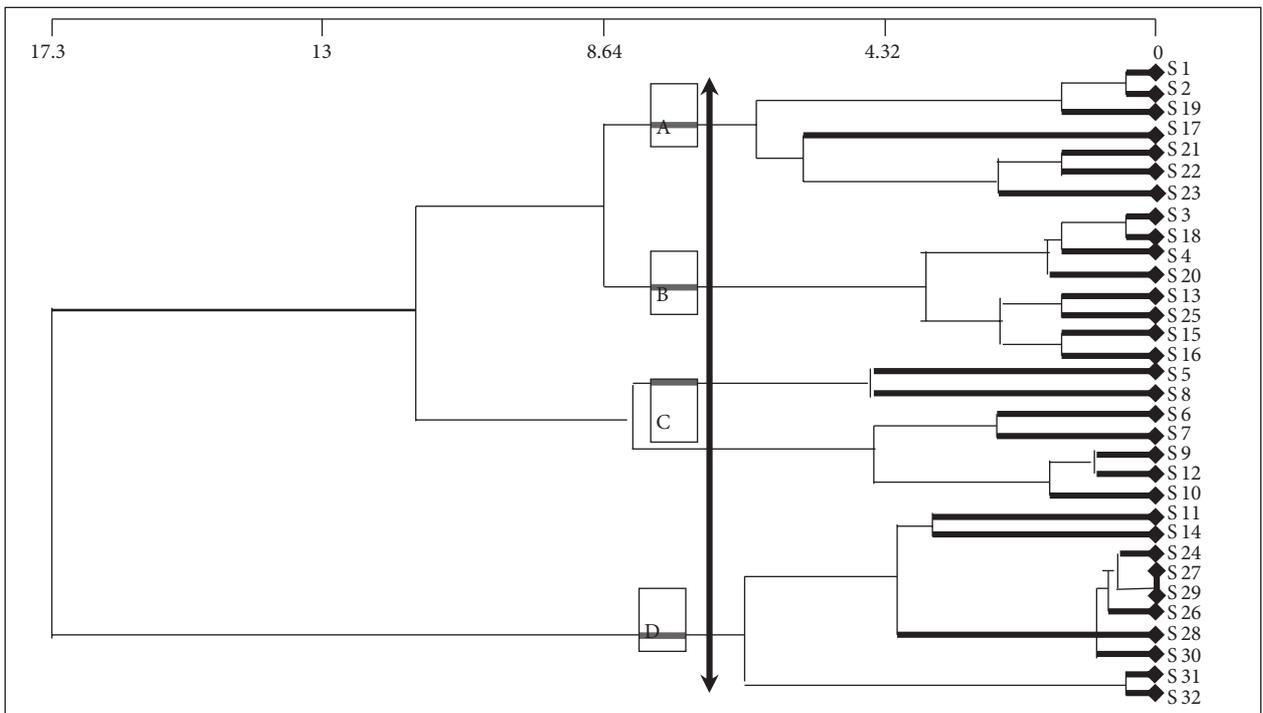


**Figure 4.** Chorological analysis of the recorded species in the study area. For abbreviations, see Table 1.

Sudano-Zambezian, Irano-Turanian, and Mediterranean regions. The Saharo-Arabian chorotype (bi- and pluri-), part of the Saharo-Arabian region, constitutes 28.1% and 16.7%, respectively, of the recorded species. Thus, it forms the major component of the floristic composition of this study.

**3.4. Multivariate analysis**

Classification of the presence/absence data set of 32 species recorded in 32 stands using cluster analysis yielded 4 vegetation groups at level 3 of the hierarchy (Figure 5; Table 2). These groups are named after the first and second dominant species as follows: (A) *Schouwia purpurea-*



**Figure 5.** Classification of the studied 32 stands using cluster analysis; A–D are the vegetation groups.

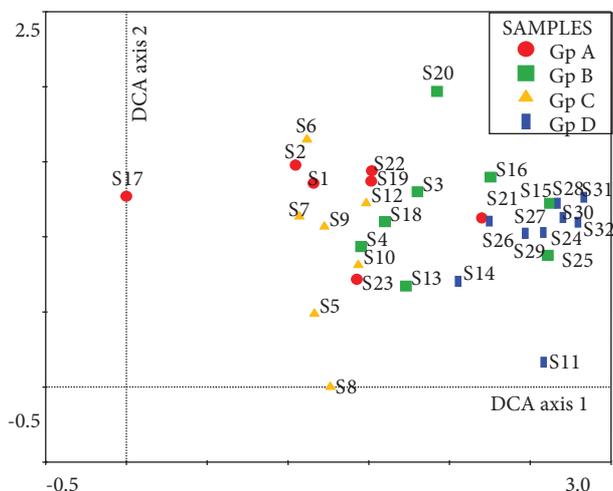
**Table 2.** Synoptic table of the vegetation groups yielded from the classification. Values in bold are species with the highest presence values.

Species	A	B	C	D
<i>Tamarix nilotica</i>	<b>100</b>	50		
<i>Schouwia purpurea</i>	<b>100</b>	100	71.4	
<i>Zygophyllum coccineum</i>	85.7	<b>100</b>	85.7	100
<i>Salsola imbricata</i> subsp. <i>imbricata</i>	85.7	100	<b>100</b>	100
<i>Launaea cassiniana</i>	85.7		85.7	<b>100</b>
<i>Haloxylon salicornicum</i>	57.1			
<i>Zilla spinosa</i>		<b>100</b>	85.7	100
<i>Zygophyllum simplex</i>		75	57.1	88.8
<i>Rumex vesicarius</i>			<b>100</b>	
<i>Malva parviflora</i>			71.4	
<i>Fagonia arabica</i>				<b>100</b>
<i>Cotula cinerea</i>				88.8

*Tamarix nilotica*, (B) *Zilla spinosa*-*Zygophyllum coccineum*, (C) *Rumex vesicarius*-*Salsola imbricata* subsp. *imbricata*, and (D) *Fagonia arabica*-*Launaea cassiniana*.

Group C was the largest (7 stands) group, including 21 species, followed by Group D (9 stands, 20 species). Some species showed a certain degree of fidelity, e.g., *Amaranthus graecizans* was confined to Group A; *Fagonia thebaica*, *F. bruuguieri*, and *Crotalaria aegyptiaca* to Group B; *Rumex vesicarius* and *Malva parviflora* to Group C; and *Astragalus hamosus*, *Lotus hebranicus*, *Pergularia tomentosa*, and *Fagonia indica* to Group D. Eight species were recorded in all groups, including *Cotula cinerea*, *Schouwia purpurea*, and *Zygophyllum simplex* as annuals and *Haloxylon salicornicum*, *Salsola imbricata* subsp. *imbricata*, and *Tamarix nilotica* as woody perennials. DCA represented the distribution of the 4 vegetation groups along the first 2 axes (Figure 6).

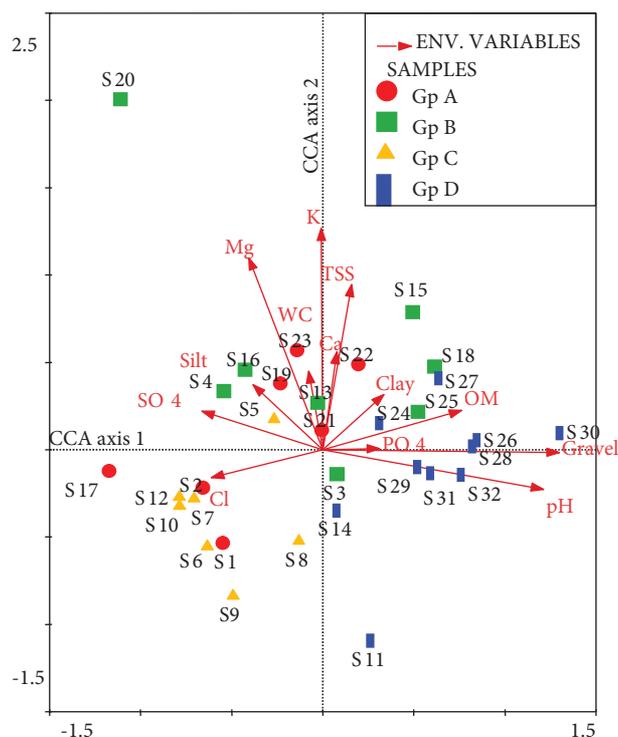
Soil characteristics of each of the 4 vegetation groups of the study were identified by cluster analysis and are summarised in Table 3. Soil reaction (pH), total soluble salts (TSS), potassium, calcium, magnesium, and chlorides showed significant differences among the identified vegetation groups. The ordination diagram produced by CCA is shown in Figure 7. The length and the direction of an arrow representing a given environmental variable provide an indication of the importance and direction of the gradient of environmental change for that variable within the set of samples measured. The cumulative percentage variance of species–environment relations



**Figure 6.** DCA ordination diagram of the 32 stands on axes 1 and 2 as classified by cluster analysis; A–D are the 4 vegetation groups.

for the 4 axes amounts to 67.6%, which suggests a strong association between vegetation and the measured parameters presented in the biplot (Jongman et al., 1987).

Stands of Group A and Group C were highly associated with chlorides. Whereas stands of Group A were highly associated with water content, stands of Group C and Group D showed the lowest levels. Gravel, clay,  $PO_4^{-3}$ , pH, and organic matter were highly associated with Group B and Group D. The intersets correlations (Table 4) resulting



**Figure 7.** CCA ordination biplot of the studies 32 stands and soil variables, together with their vegetation groups.

from the CCA demonstrated that CCA axis 1 was highly positively correlated with gravel and pH and negatively correlated with  $\text{SO}_4^{-2}$  and chlorides. This axis can be identified as the gravel- $\text{SO}_4^{-2}$  gradient. CCA axis 2 was highly positively correlated with  $\text{K}^+$ ,  $\text{Mg}^{+2}$ , and total soluble salts and negatively correlated with pH. This axis can be identified as the K-pH gradient. A test for significance with an unrestricted Monte Carlo permutation test found the F-ratio for the eigenvalue of CCA axis 1 and the trace statistics to be significant ( $P < 0.05$ ), indicating that the observed patterns did not arise by chance.

#### 4. Discussion

In extreme arid conditions, as in the present study area, plant life is restricted to microenvironments where runoff water collects and provides sufficient moisture for plant growth. This was described by Monod (1954) as *végétation contracté*, runoff desert (Zohary, 1962), and restricted desert (Walter, 1963). Here the vegetation is restricted to wadis, runnels, and depressions with deep, fine sediments that receive adequate water supply. Zohary (1973) classified the desert vegetation of the Middle East into 2 main types: stony and gravelly. The first type includes *Anabasetalia articulatae*, *Zygophyllatalia dumosi*, and *Salsoletalia tetrandrae*, while the second type is represented in Egypt

**Table 3.** Mean values, standard errors, and ANOVA F-values of the soil variables in the 32 stands representing the 4 vegetation groups (A-D) obtained by cluster analysis. \* $P < 0.05$ , \*\* $P < 0.01$ .

Soil variables	Vegetation groups				F-ratio
	A	B	C	D	
pH	8.6 ± 0.3	8.2 ± 0.3	8.4 ± 0.3	8.8 ± 0.3	7.69**
Total soluble salts (mg/L)	2.7 ± 3.8	6.4 ± 4.6	78.2 ± 3.9	1.08 ± 7.2	6.2**
Gravel	2.3 ± 1.6	3.6 ± 5.4	0.39 ± 0.44	6.6 ± 6.4	2.75
Silt	18.4 ± 11.4	23.2 ± 9.5	21.2 ± 14.6	17.2 ± 12.7	0.43
Clay	7.5 ± 5.0	7.2 ± 2.9	6.0 ± 2.7	8.8 ± 7.5	0.41
Organic matter	2.4 ± 1.2	3.2 ± 1.0	2.3 ± 1.5	2.8 ± 1.2	0.82
Water content	0.4 ± 0.6	0.3 ± 0.2	0.1 ± 0.1	0.1 ± 0.1	1.4
$\text{K}^+$	0.1 ± 0.09	0.23 ± 0.07	0.05 ± 0.04	0.06 ± 0.05	13.3**
$\text{Ca}^{+2}$	0.4 ± 0.3	0.7 ± 0.4	0.3 ± 0.09	0.3 ± 0.14	4.8**
$\text{Mg}^{+2}$	0.2 ± 0.1	0.3 ± 0.1	0.1 ± 0.05	0.1 ± 0.05	7.9**
$\text{Cl}^-$	1.0 ± 0.4	1.4 ± 0.4	1.2 ± 0.2	0.9 ± 0.3	3.6*
$\text{SO}_4^{-2}$	4.2 ± 0.5	3.9 ± 1.5	3.5 ± 0.3	2.9 ± 1.2	2.17
$\text{PO}_4^{-3}$	0.17 ± 0.06	0.20 ± 0.04	0.2 ± 0.08	0.2 ± 0.05	2.3

**Table 4.** Results of ordination for the first 3 axes of CCA. Inter-set correlations of the soil variables are given together with eigenvalues and species–environment correlation coefficients. For units, see Table 3.

	CCA axis		
	1	2	3
Eigenvalues	0.273	0.225	0.153
Species–environment correlation coefficients	0.917	0.926	0.787
pH	0.45	–0.09	0.15
TSS	–0.05	0.38	–0.02
Gravel	0.48	–0.01	0.13
Silt	–0.014	0.15	–0.38
Clay	0.13	0.13	–0.15
Organic matter	0.28	0.09	–0.18
Water content	–0.03	0.18	–0.06
K <sup>+</sup>	–0.003	0.51	–0.14
Ca <sup>+2</sup>	0.03	0.23	–0.11
Mg <sup>+2</sup>	–0.15	0.44	0.17
Cl <sup>–</sup>	–0.23	–0.06	–0.26
SO <sub>4</sub> <sup>–2</sup>	–0.25	0.09	0.17
PO <sub>4</sub> <sup>–3</sup>	0.11	0.002	–0.43

by the orders *Ammophiletalia*, *Stipagrosti–Retametalia*, and *Haloxylon–Retametalia*. The latter order and some of its associations, namely *Pituranthes tortuosi*, *Artemisiaetum monospermae*, and *Panicetum turgidi*, are comparable to those groupings identified in the present study. It is easy to stipulate the general picture of vegetation in the studied wadis as a result of sudden torrential events that occurred in 2010. The study area was subjected to an earlier similar torrential event in 1980 (El-Sharkawi et al., 1982a).

Floristic analysis of the recorded flora has been compared with an earlier study of the same area (El-Sharkawi et al., 1982a, 1982b), which revealed the disappearance of 7 species (*Launaea capitata*, *Plantago ciliata*, *Arnebia hispidissima*, and *Forsskalea tenacisdsima*, amongst others), while 16 species were newly recorded (*Diploaxis acris*, *Launaea cassiniana*, *Lotus hebranicus*, and *Pergularia tomentosa*, amongst others). Sixteen other species were constantly recorded (*Zilla spinosa*, *Zygophyllum coccineum*, *Schouwia purpurea*, *Haloxylon salicornicum*, and *Citrullus colocynthis*, amongst others). The invasion of the area by such species during the last 3 decades may be attributed to the new land-use system in the region (e.g., tourist resorts, construction of highways,

water pipelines, land reclamation projects, and medicinal and ornamental plantations).

Phytogeographically, the Saharo-Arabian element forms the major component of the floristic structure because the study area lies within the Saharo-Arabian region of the Holarctic Kingdom. In contrast, the monoregional Sudano-Zambezi element is poorly represented. Thus, the shrub layer is composed mainly of the Saharo-Arabian with a Sudano-Zambezi focus of distribution. Pure Mediterranean taxa are not represented in the therophyte and chamaephyte layers, whereas they are represented in the bi- and pluriregional taxa. This may be attributed to the fact that plants of the Saharo-Arabian region are good indicators for desert environmental conditions, while Mediterranean species represent more mesic environments.

The life-form spectrum in the present study is characteristic of an arid desert region with the dominance of chamaephytes (31% of the recorded species) and therophytes (28%), followed by hemicryptophytes and phanerophytes (19% for each). Preponderance of annuals and shrubs reflects a typical desert flora, where it is closely related with topography (Zohary, 1973; Orshan, 1986). On the other hand, they may be a response to the

hot, dry climate and human and animal interferences. The remarkably high percentages of phanerophytes and chamaephytes (16.2% for both) must also be emphasised. The dominant perennials were the nonsucculent trees and shrubs (or subshrubs) and the perennial herbs. Some of these perennials are drought-enduring plants in which the photosynthetically and transpiring organs were maintained at nearly constant proportions (Abdel-Razik et al., 1984). A comparison of the life-form spectra of the northern part of the Eastern Desert of Egypt (Abd El-Ghani, 1998) and those in the Tihama coastal plains of the Jizan region in south-western Saudi Arabia (El-Demerdash et al., 1994) showed the same results.

Spatial distribution of plant species and communities over a small geographic area in desert ecosystems is related to heterogeneous topography and landform pattern (Parker, 1991). The heterogeneity of local topography, edaphic factors, and microhabitat conditions leads to variation of the distribution of the plant communities in the study area. Two approaches of multivariate analysis were used in this study, namely classification and ordination. In terms of classification, the vegetation that characterises the investigated area can be divided into 4 vegetation groups: (A) *Schouwia purpurea-Tamarix nilotica*, (B) *Zilla spinosa-Zygophyllum coccineum*, (C) *Rumex vesicarius-Salsola imbricata* subsp. *imbricata*, and (D) *Fagonia arabica-*

*Launaea cassiniana*. In their detailed study on the plant communities in the vicinity of this study area, El-Sharkawi et al. (1982b) described 3 major community types. The first included *Zilla spinosa*, *Zygophyllum coccineum*, *Schouwia thebaica*, *Zygophyllum simplex*, *Cotula cinerea*, *Salsola baryosma*, *Pulicaria undulata*, *Tribulus pentandrus*, and *Launaea capitata*. The second included *Fagonia bruguieri*, *Morettia philaeana*, *Citrullus colocynthis*, *Lotononis platycarpa*, *Astragalus vogelii*, and *Crotalaria aegyptiaca*. The third included *Rumex vesicarius*, *Malva parviflora*, *Astragalus eremophilus*, and *Trichodesma africanum*. Certainly, the identified vegetation groups belong to these community types. Analysis of the vegetation–soil relationships using CCA indicated that the distribution of vegetation in the study area was mainly controlled by gravel, pH, SO<sub>4</sub>, chlorides, K, Mg, and TSS. The percentage of surface sediments of different size classes determines the spatial distribution of soil moisture (Yair et al., 1980; El-Ghareeb & Shabana, 1990).

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