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A Comparative Study on the Vegetation of Two Wadis, Sinai Peninsula

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This study evaluated the effect of edaphic factors on species diversity and distribution of vegetation in Wadi El-Fath and Wadi Nukhul in Sinai Peninsula. Selection of stands was depending on the change in the vegetation along the two Wadis. The study includes 20 stands; ten in each Wadi. In Wadi Nukhul 28 species belonging to 14 families were recorded where the abundant family was Chenopodiaceae (21.43%). Meanwhile 55 species belonging to 21 families were recorded in Wadi El-Fath; the abundant families were Astraceae and Zygophyllaceae (each 10.91 %). Chamaephytes were the dominant life forms in the two studied Wadis. Chorology of the two Wadis showed the dominance of the monoregional Saharo-Arabian chorotype. The application of TWINSPAN led to the recognition of eight vegetational groups. The first four represented Wadi Nukhul, while the others represented Wadi El-Fath. Soil texture of Wadi Nukhul was medium sand, while that of Wadi El-Fath was fine sand. Moisture content in Wadi El-Fath was higher than that in Wadi Nukhul. CCA analysis indicated that the vegetational groups of Wadi Nukhul affected by soil chemical properties, whereas its physical properties affected the vegetational group of Wadi El-Fath.

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Soil texture and moisture content were the most important edaphic factors affect the distribution of plant species in the two studied Wadis. Biodiversity indices revealed that Wadi El-Fath was more diverse than Wadi Nukhul; the highest species richness was found at the hills habitat in Wadi El-Fath (22.0). While, the lowest mean species richness of 1.0±0.7 was recorded in the bounding sides of Wadi Nukhul..

Key Words: Diversity, TWINSPAN, CCA, Wadi, El-Fath, Nukhul and Sinai Peninsula.

Introduction

Vegetation has been widely used to describe habitats, water quality and make predictions about the presence and composition of the surrounding communities (Appelgren and Mattila, 2005). In Egypt, desert vegetation is the most important and characteristic type of natural plant life. It covers vast area and is formed mainly of xerophytic shrubs and sub-shrubs (Abd El-Ghani *et al.*, 2003). Annual plants represent 50-60% of the desert vegetation during the rainy season (Kassas, 1966). Change in the existent components of a natural ecosystem, especially plants and soil, leads to gradual variations in the shape, composition and structure of such communities. Therefore, studying the classification and the inter-relation between the different plant communities in response to the environmental factors are demand (Jafari *et al.*, 2003). Inter-relationships between plant communities and environmental factors are complex, reflecting simultaneous changes in factors such as ground-water depth, soil moisture, soil stability and salt content (Zhang *et al.*, 2005). The effects of environmental factors on plant communities have been the subject of many ecological studies. Jafari *et al.* (2004) revealed that the vegetation distribution pattern in rangelands of Yazd Province (Iran) was mainly related to soil texture and moisture contents. Youssef *et al.* (2009) stated that the plant species is generally determined by climate, geomorphology and influenced by soil conditions during their studies on vegetation of the coastal areas in Saudi Arabia. However, Zegeye *et al.* (2006) showed that the interdependency of vegetation type and soil chemical properties lead to a variety of species, vegetation types and distribution of plant communities The vegetation of Sinai, being a bridge between Africa and Asia, reflects the influence of different phytogeographical regions that meet and overlap in the peninsula.

Accordingly, phytogeographically, Sinai Peninsula belongs to four plant geographical regions: 1) Mediterranean, forest and shrub vegetation, 2) Irano–turanian with steppes vegetation, 3) Saharo–Arabian with desert vegetation and 4) Sudanian penetrations with savanna like vegetation. These four regions superimposed in the great diversity of climate, rock and soil types that make possible the existence of 900 species and 250-300 associations (Danin, 1986). The main habitats and the relation between the distribution behaviour of common plant species and the environmental factors on different stands of Wadi El-Fath in addition to the chemical evaluation of their potentialities for grazing and medicinal purposes were discussed by Dames and More (1981). Girgis and Ahmed (1985) determined three main sectors in Wadi Nukhul; upstream dominated by *Acacia raddiana* and *Haloxylon salicornicum*, midstream dominated by *Haloxylon salicornicum* and downstream dominated by *Zygophyllum coccineum*. *Capparis sinaica* and C. *spinosa* were recorded hanged on the bounding sides of the Wadi at different heights. The objectives of the present study are to analyze the vegetation in Wadis El-Fath and Nukhul in Sinai Peninsula. The study also assesses the correlation between the environmental factors and some of vegetation variables in order to determine the distribution of species and communities along the study area.

Study Area

Two Wadis in two different regions in Sinai Peninsula were selected; Wadi Nukhul near Abu Zeneima city and Wadi El-Fath in El-Maghara area. The distance between the two studied Wadis is about 197.217 km (Fig. 1).

Wadi Nukhul (coastal Wadi) lies between latitudes 29° 04' N (upstream) - 29° 01' N (downstream) and longitudes 33° 13' E (upstream) - 33° 10' E (downstream). It drains into Gulf of Suez at Abu Zenima "about 6 km south of Abu Zenima City, southwestern of Sinai". It has relatively short channel 15 km with much branched courses during the majority of its channel which cut through limestone (Cretaceous-Eocene) formations forming very well defined much ramified courses and have very deep sides. It has no side terraces and its catchments area is not extensive. The surface deposits are mostly compact formed mainly of mixed sandy calcareous matrix including vari-sized rock detritus. The upper reaches of this Wadi are near to sources of Nubian sandstone, viz. Dabbet El-Gerai, the southern slopes of El-Tih plateau and Gebel Nukhul (Girgis and Ahmed, 1985 and Obaidalla, 2005).

Wadi El-Fath (inland Wadi) lies between latitudes 30° 45' N (upstream) - 30° 48' N (downstream) and longitudes 33° 29' E (upstream) - 33° 38' E (downstream). The major part of this Wadi is a main trunk runs nearly in E.W. direction for about 15 km. It is one of the main drainage systems of Gebel El-Maghara (the largest Jurassic exposure in Egypt). The contact between the Jurassic and cretaceous sediments is obscured by Wadi fill. Its upstream portion consists of two branches, Wadi El-Mezeira (in the northeast) and Wadi El-Maghara (on the southwest). Downstream from this connection, Wadi El-Fath flows in a NNW direction for about 7 km, where it connected with two tributaries, i.e. Wadi El-Karm and Wadi El-Masajid "Wadi El-Mezeira join Wadi El-Masajid at the environ of El-Fath Village, the main trunk of Wadi El-Fath extends in an east west trend for about 5 km long sector in which it receives the last main sub-basin that called Wadi El-Karm.". The concerned Wadi is almost cut down through brittle and soft subsoil bedrock with sparse vegetation. It has moderate groundwater potentiality and flooding possibility. The Aeolian deposits dominate Wadi El-Fath represented by drift sand accumulations in the form of undulating sand sheets or scattered movable dunes which sometimes block the roads. These dunes area are largely shaped by the north western winds and acquire various forms (Mohamed, 1997 and Khaled, 2000).

Climate

McGinnies *et al.*, (1968) and Danin, (1983) stated that Sinai Peninsula desert belongs to the Arabian desert characterized by: 1) Arid to extremely arid climate with Mediterranean influence, 2) Precipitation mostly in winter ranges 250 mm at the northern boundary (Negev Desert) to 10–20 mm in the south of Sinai and 3) Mean temperature of 10–20° C in the coldest months and 20–30° C in the warmest months. Moisture in the form of rainfall is the most decisive factor controlling productivity, plant distribution and life forms in arid region area (Zohary, 1973). Table (1) shows the climatic means of El-Maghara and Abu Rudies meteorological stations; the nearest stations to the studied Wadis.

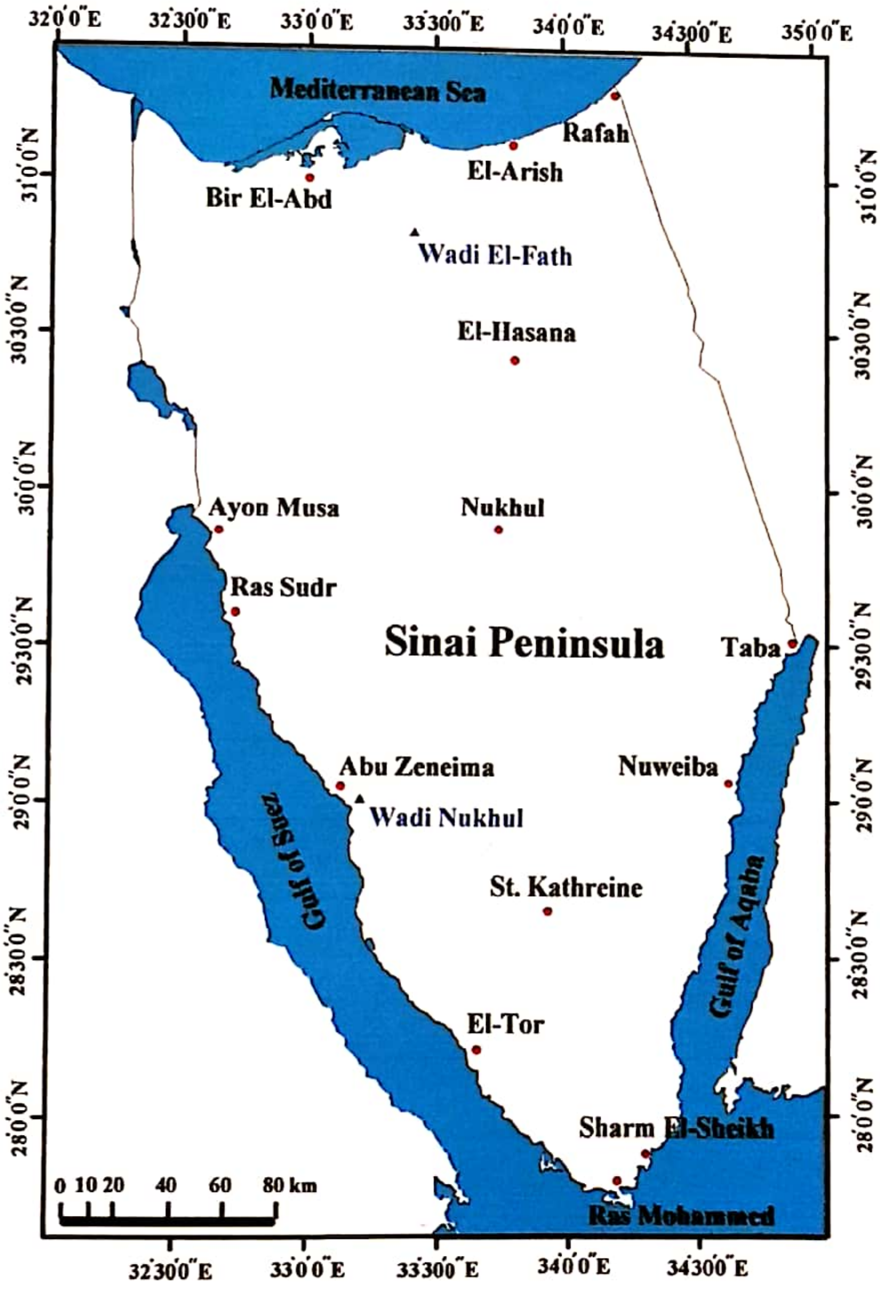


Figure (1). A map of Sinai Peninsula showing the location of the two studied Wadis.

Table (1). Climatic records of El-Maghara and Abu Rudies meteorological stations (Climatic means of 5 years from 2001 - 2005).

Station / Month	El-Maghara (Wadi El-Fath)				Abu Rudeis (Wadi Nukhul)			
M. data	A	B	C	D	A	B	C	D
January	19.62	4.03	73.03	6.72	14.8	5.1	55	21.8
February	19.46	3.11	70.58	7.34	15.35	7.6	51	22.2
March	20.71	1.23	73.1	8.57	18.45	1.1	51	19.2
April	22.25	1.02	70.2	7.63	22.15	0.4	49	25
May	23.27	0	71.77	7.76	25.65	0.1	50	22.2
June	25.42	0	72.45	7.32	27.75	0	52	35.3
July	26.94	0	70.43	7.03	28.95	0	54	32.4
August	29.05	0	70.76	6.97	29.2	0	56	37.9
September	28.12	0	66.53	6.36	27.6	0	58	33.9
October	26.96	0	72	6.73	22.9	0.2	58	19.4
November	26.25	3	70.95	7.58	20.45	1.8	54	13.1
December	22.87	2.99	69.4	6.92	16.95	11.8	55	13
Total Annual rainfall	15.38				28.1			
Annual mean temp.	24.24				22.52			

A = Monthly mean temperature ° C, B = Monthly total Rainfall mm, C = Relative humidity % and D = Wind velocity km/hr.

Materials and methods

1. Vegetation sampling procedures

The present study was represented by two main drainage systems (Wadi Nukhul and Wadi El-Fath). The field studies of the present work conducted through regular visits during two successive years 2007 and 2008. The selection of stands was depending on the change in the vegetation structure and composition along the two Wadis. The study includes 20 georeferenced stands using GPS device (Magellan GPS 315) and distributed as follows: 10 from the upstream part of Wadi Nukhul to its downstream part on Suez Gulf and 10 from the upstream of Wadi El-Fath to its delta. Each stand was vegetationally analyzed by using quadrate methods that were randomly positioned along the two selected Wadis. The species in each quadrate were listed, and the number of individuals of each species was counted and used in the estimation of its absolute and relative densities. The number of occurrences of a species in quadrates of each stand was used to calculate its absolute and relative frequencies. The coverage of a species was estimated by using the line-intercept method. The relative values of density, frequency and cover for each species were summed up to give its importance value (IV) out of 300 (Curtis & McIntosh, 1950; Ludwig & Reynolds, 1988).

The phytogeographical (chorology) categories of the recorded plant species were based on Zohary, (1966, 1972) Feinbrun-Dothan, (1978, 1986) Danin, (2006). The recorded species were classified according Raunkiaer's life-form classification system (Raunkiaer, 1934). The taxonomical nomenclature of the plant species was after Täckholm (1974), Boulos (1995, 1999, 2000, 2002 & 2005).

2. Soil sampling and analysis

Soil samples were collected from the freshly exposed surface layers (0-20 cm) and subsurface layer (20-40 cm), air-dried, and kept for determination of soil texture (Udden, 1914; Wentworth, 1922; Krumbein and Sloss, 1963; Ryan *et al.*, 1996), pH was measured by using a portable pH-meter (Model, inolab pH level 1), electrical conductivity was measured by using a portable conductivity meter (YSI Model, 35) (Richards, 1954), Chlorides were estimated by titration methods (Jackson, 1967), Sulphates were estimated by the turbidimetric method (Standard methods, 1989) and measured by spectrophotometer (Model, Spectronic 20 D). Sodium and potassium by using flame photometer (JENWAY PEP 7), HCO_3^-, Ca^{2+} and Mg^{2+} were estimated by titration methods (Richards, 1954 and Ryan *et al.*, 1996). Calcium carbonate was determined volumetrically using Collin's Calcimeter, Piper (1950).

3. Multivariate analysis procedures

In the present study, two trends of multivariate analysis were applied on the collected data: Two Way Indicator Species Analysis (TWINSPAN) (Hill, 1979; Gauch & Whittaker, 1981) was used for classification of samples stands into definite vegetation groups and Canonical Correspondence Analysis; (CCA) (Ter Braak & Prentice, 1988) was used for ordination. The input data in both techniques were in two forms: stands versus species important values (I.V.) data matrix (20 stands × 56 species) and stands versus environmental factors data matrix (20 stands × 19 soil parameters) respectively. TWINSPAN classification was carried out by using a computer program (CAP, Community Analysis Package, version 1.3.1, Henderson & Seaby, 1999). CCA was performed by using CANOCO for windows program, version 4.5.2., Ter Braak and Smilauer (2002) and PC-ORD Software version 4.37 (McCune & Mefford, 2005).

4. Biodiversity indices:

Four biodiversity indices were calculated for the different vegetational groups identified by the TWINSPAN numerical classification technique according to (Pielou 1975, Ludwig & Reynolds (1988) and Magurran 1988 & 2004) these Indices are described as follows:

Species richness (α-diversity) for each vegetation group was calculated as the average number of species per stand, and Species turnover (β-diversity) as the ratio between the total number of species recorded in a certain vegetation group and its alpha diversity (Whittaker 1972 & Wilson and Shmida 1984). Relative equitability or evenness of the importance value of species was expressed according to Shannon diversity index (H') (Perkins, 1982):

$$H` = -\sum_{i=1}^{S} Pi \, Ln\,(Pi)$$

The heterogeneity dominance measure was expressed by the Simpson index:

$$C = \sum_{i=1}^{S} Pi^2$$

where, S = the total number of species, Pi = the relative importance value of the i^{th} species. All the computations were done by using a computer program (Biodiversity Professional, Version 2.0, McAleece *et. al.* 1997).

Results and Discussion

1. Floristic relations

Floristic composition is a function of the relation between plants and their habitat. In the present study there were differences in the floristic composition of the two studied Wadis. A complete list of scientific names and families of the recorded species in the study area was presented in Table (2). From this table, the total number of the recorded plant species in the study area were 68 species (56 perennials and 12 annuals) belonging to 57 genera and representing 23 families. These families were distributed as 2 Monocotyledons and 21 Dicotyledons. In Wadi Nukhul; a total of 28 species belonging to 14 families were recorded out of these 27 were perennials and 1 annual; the abundant families in Wadi Nukhul were Chenopodiaceae (21.43%), Zygophyllaceae (14.29%) and Fabaceae

(10.71%). Meanwhile a total of 55 species belonging to 21 families were recorded in Wadi El-Fath out of these 43 were perennials and 12 annuals; the abundant families in Wadi El-Fath were Zygophyllaceae and Astraceae (each 10.91%), Poaceae (9.09%), Brassicaceae, Chenopodiaceae and Fabaceae (each 7.27%).

15 species belonging to 14 genera and 12 families recorded in the two studied Wadis such as *Acacia raddiana*, *Fagonia arabica*, *Haloxylon salicornicum*, *Retama raetam*, *Zilla spinosa* and *Zygophyllum coccineum*. Only two families with 3 species recorded in Wadi Nukhul only: Capparaceae (*Capparis spinosa* L. & *Capparis sinaica* Veill.) and Cucurbitaceae (*Citrullus colocynthis* (L.) Schrad.), while 9 families with 16 species recorded in Wadi El-Fath only of these: Asclepiadaceae, Convolvulaceae, Euphorbiaceae, Solanaceae and Thymelaeaceae.

Girgis and Ahmed (1985) in their survey of Wadi Nukhul recorded about 77 species (44 perrenials and 33 annuals) from these only 28 species were recorded in this study and 49 species disappeared such as: *Phragmites australis*, *Juncus rigidus*, *Blepharis attenuata*, *Iflago spicata*, *Plantago ovata* and *Rumex vesicarius*.

Table (2). The recorded species and each family contribution in the flora of the study area.

Family	Species
Asclepiadaceae (1.47%)	*pergularia tomentosa* L. *
Astraceae (10.29%)	*Achillea fragrantissima* (Forssk.) Sch. Bip. *
	Achillea santolina L. *
	Artemesia monosperma Delile *
	Echinops spinosus L. *
	Iphiona mucronata (Forssk.) Asch. & Schweinf. **
	Launaea nudicaulis (L.) Hook.f. *
	Pulicaria undulata (L.) C.A.Mey. ***
Boraginaceae (1.47%)	*Heliotropium arbainense* Fresen. ***
Brassicaceae	*Farsetia aegyptia* Turra *

(5.88%)	*Moricandia nitens* (Viv.) Durand & Barratte *
	Savignya parviflora (Delile) Webb ***
	Zilla spinosa (L.) Prantl ***
Capparaceae (2.94%)	*Capparis sinaica* Veill. **
	Capparis spinosa L. **
Caryophyllacaea (4.41%)	*Gymnocarpos decander* Forssk. ***
	Paronychia arabica (L.) DC. *
	Polycarpon succulentum (Delile) j.Gay *
Chenopodiaceae (13.24%)	*Anabasis articulata* (Forssk.) Moq. **
	Anabasis setifera Moq. **
	Atriplex leucoclada Boiss. **
	Bassia indica (Wight) A.J.Scott *
	Cornulaca monocantha Delile *
	Haloxylon salicornicum (Moq.) Bunge ex Boiss. ***
	Noaea mucronata (Forssk.) Asch. & Schweinf. *
	Salsola tetrandra Forssk. **
	Suaeda vermiculata Forssk.ex J.F. Gmel. **
Cleomaceae (2.94%)	*Cleome amblyocarpa* Barratte & Murb. *
	Cleome droserifolia (Forssk.) Delile **
Convolvulaceae (2.94%)	*Convolvulus arvensis* L. *
	Convolvulus lanatus Vahl *
Cucurbitaceae (1.47%)	*Citrullus colocynthis* (L.) Schrad. **
Euphorbiaceae (4.41%)	*Andrachne aspera* Spreng. *
	Euphorbia peplus L. *
	Euphorbia retusa Forssk. *
Fabaceae (7.35%)	*Acacia tortilis* (Forssk.) Hayne supsp. *raddiana* (Savi) Brenan ***

	Alhagi graecorum Boiss. *
	Crotalaria aegyptiaca Benth. **
	Retama raetam (Forssk.) Webb & Berthel ***
	Trigonella stellata Forssk. *
Geraniaceae (1.47%)	*Erodium crassifolium* L' Hér. *
Liliaceae (4.41%)	*Asparagus stipularis* Forssk. *
	Asphodelus tenuifolius Cav. *
	Urginea maritima (L.) Baker *
Malvaceae (1.47%)	*Malva parviflora* L. *
Nitrariacaea (1.47%)	*Nitraria retusa* (Forssk.) Asch ***
Poaceae (7.35%)	*Cutandia dichotoma* (Forssk.) Trab. *
	Cynodon dactylon (L.) Pers *
	Panicum turgidum Forssk. ***
	Stipagrostis plumosa (L.)Munro ex T. Anderson *
	Phragmites australis (Cor.) Trin. *
Primulaceae (1.47%)	*Anagallis arvensis* L. *
Resedaceae (2.94%)	*Ochradenus baccatus* Delile ***
	Reseda alba L. *
Solanaceae (4.41%)	*Hyoscyamus muticus* L. *
	Lycium shawii Roem. & Schult. *
	Solanum nigrum L. *
Tamaricaceae (4.41%)	*Reaumuria hirtella* Jaub. & Spach **
	Tamarix aphylla (L.) H.Karst. *
	Tamarix nilotica (Ehrenb.) Bunge ***
Thymelaeaceae (1.47%)	*Thymelaea hirsuta* (L.) Endl. *
Zygophyllaceae (10.29%)	*Fagonia arabica* L. ***
	Fagonia indica Burm.f. *
	Fagonia mollis Delile ***

	Peganum harmala L. *
	Zygophyllum album L. f. **
	Zygophyllum coccineum L. ***
	Zygophyllum dumosum Boiss. *

*: species recorded in Wadi El-Fath only
**: species recorded in Wadi Nukhul only
***: species recorded in the two Wadis

As shown in figure 2, only four life forms characterized the vegetation of Wadi Nukhul which were Chamaephytes (71.43%), Phanerophytes (21.43%), Hemicryptophytes and Therophytes (each 3.57%). While five life forms characterized the vegetation of Wadi El-Fath which were Chamaephytes (38.18%), Therophytes (21.82%), Hemicryptophytes (18.18%), Phanerophytes (14.55%) and Geophytes (7.27%). Chamaephytes were the dominant life forms in the two studied Wadis. This agreed with (Ayyad & El Kady 1982; Shaltout *et al.* 1996 and El Banna *et al.* 2002) whose stated that shrubs and under-shrubs are the major components of arid and semi arid rangelands through out Egypt and the world. Annual (Therophytes) species were restricted to habitat with high water content, sedimentary, fine grained particles and low soil salinity.

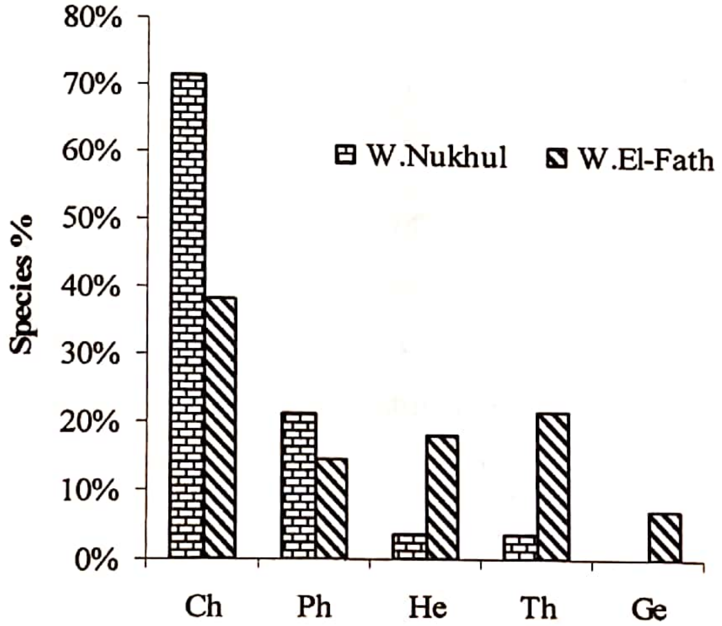


Figure (2). The life form classes in the two studied Wadis.
Ch = Chamaephytes, Ph = Phanerophytes, He = Hemicryptophytes, Th = Therophytes and Ge = Geophytes.

Analysis of Wadi Nukhul and Wadi El-Fath showed the presence of the monoregional Saharo-Arabian chorotype in a higher percentage than the inter-regional chorotypes (Table 3). The Saharo-Arabian chorotype decreased northward (from Wadi Nukhul to Wadi El-Fath) and replaced by Mediterranean and Irano-Turanian chorotype (Danin & Plitman, 1987 and Hegazy & Amer, 2001). In Wadi Nukhul 24 species were monoregional with value (85.71%), 4 species were biregional (14.29%) and there is no any pluriregional species were recorded, while in Wadi El-Fath 34 species were monoregional with value (61.82%), 15 species were biregional (27.27%) and the pluriregional (10.91%) had 6 species .

Table (3). Chorological analysis of the examined species as numbers and percentages of the species recorded in the study area.

Phytochoria	No. of Species in Wadi Nukhul	% of Sp. in Wadi Nukhul	No. of Species in Wadi El-Fath	% of Sp. in Wadi El-Fath
I- Monoregional				
Sudanian	6	21.43	7	12.73
Saharo-Arabian	17	60.71	25	45.46
Mediteranean	1	3.57	1	1.82
Irano-Turanian	0	0	1	1.82
Total	**24**	**85.71**	**34**	**61.82**
II- Biregional				
Mediterranean + Irano-Turanian	0	0	3	5.46
Saharo-Arabian + Mediterranean	0	0	3	5.46
Saharo-Arabian + Irano-Turanian	2	7.14	4	7.27
Saharo-Arabian + Sudanian	2	7.14	5	9.09
Total	**4**	**14.28**	**15**	**27.27**
III- Pluriregional				
Mediteranean + Irano-Turanian + Saharo-Arabian	0	0	2	3.64
Euro-Siberian + Mediterranean + Irano-Turanian	0	0	3	5.46
Pluriregionablebor-trop	0	0	1	1.82
Total	**0**	**0**	**6**	**10.91**
Total of all species	**28**	**100**	**55**	**100**

2. Multivariate analysis

2.1. Classification

The application of TWINSPAN classification on the importance values of 56 species led to the recognition of 8 groups (Fig. 3). The characterizations of the vegetation groups of the two Wadis were presented in (Table 4). Each group comprised a set of stands with greater homogeneity of vegetation. Each Wadi contained 4 groups. The first four vegetational groups represented Wadi Nukhul (I, II, III and IV) while the others represented Wadi El-Fath (V, VI, VII and VIII).

Wadi Nukhul groups:

Group I. This group consisted of two stands and two species. It inhabited the sides of Wadi Nukhul. The leading dominant species of this group was *Capparis spinosa* (I.V.=204.24), while the co-dominant species was *Capparis sinaica* (I.V.=95.76). The two species were recorded hanged on the bounding sides of the Wadi at different heights (habitat: hard rock outcrops Danin, 2006). The mean soil physicochemical parameters in this group showed The highest values of very coarse sand, silt & clay, E.C., Na^+, K^+, Mg^{2+}, HCO_3^-, Cl^-, SO_4^{2-} and $CaCO_3$ % (11.69 %, 16.76%,12.51 mlmohs L^{1-}, 156.50 meq L^{1-}, 14.79 meq L^{1-}, 26.25 meq L^{1-}, 10.15 meq L^{1-}, 121.88 meq L^{1-}, 10.83 meq L^{1-} and 40.75% respectively), and the lowest values of fine sand and pH (13.81% and 7.43 respectively). The E.C., most of mineral content and $CaCO_3$% reach its maximum in this group it may be due to water falling on the mountains runs over the slopes and collects in the narrow deep Wadis where it forms perpetual steams and rivulets (Zahran & Willis, 2009). This water cause leaching of the mineral contents in the main channel of the Wadi to the lower layers meanwhile this leaching does not occur in the bounding sides of the Wadi.

Group II. This group had only two stands and ten species. This group occupied the upstream portion of Wadi Nukhul. The leading dominant species of this group was *Haloxylon salicornicum* (I.V.=130.45). The co-dominant species included three species. These are *Anabasis setifera* (I.V.=33.48) *Ochradenus baccatus* (I.V.=32.69) and *Salsola tetrandra* (I.V.=28.97). The mean soil physicochemical parameters in this group showed the highest mean value of medium sand 46% and the lowest values of very fine gravel, moisture winter % and bicarbonate anion concentration (2.23%, 0.18 and 0.6 meq L^{1-} respectively).

Group III. It comprised four stands and twenty four species. This group occupied the middle and downstream portions of this Wadi. The leading dominant species of this group was *Haloxylon salicornicum* (I.V.=56.86). The co-dominant species comprised *Zygophyllum coccineum* (I.V.=52.32), *Tamarix nilotica* (I.V.=49.80) and *Anabasis setifera* (I.V.=24.09). The mean soil physicochemical parameters in this group showed the highest value of Ca^{2+} 25.41 meq L^{1-}. While, moisture content in summer attained the lowest mean value 0.11%.

Group IV. It encompassed two stands and nine species. This group inhabited the channel of Wadi Nukhul in the upstream part which is often narrow cutting across Nubian sandstone formations (Girgis and Ahmed, 1985). The leading dominant species of this group was *Acacia raddiana* (I.V.=97.73), while the co-dominant species included *Haloxylon salicornicum* (I.V.=93.56), *Ochradenus baccatus* (I.V.=47.75) and *Zilla spinosa* (I.V.=27.12). The mean soil physicochemical parameters in this group showed the minimum values of very fine sand 2.10%, $CaCO_3$ 3.50% and chloride 0.75 meq L^{1-}.

The first group inhabited the bounding sides of Wadi Nukhul while the others occupied the main channel of the Wadi (upstream, middle and downstream). This result was agreed with Girgis and Ahmed (1985).

***Wadi El-Fath groups*:**

Group V. It comprised only one stand and eighteen species. This group inhabited near the well of El-Fath Village. The leading dominant species of this group was *Haloxylon salicornicum* (I.V.=52.57), while the co-dominant species include *Zilla spinosa* (I.V.=52.03), *Peganum harmala* (I.V.=26.21), *Farsetia aegyptia* (I.V.=22.84) and *Retama raetam* (I.V.=17.48). Table (4) showed that soil supporting group V scored the highest mean values of very fine sand 27.89%, moisture content in winter and in summer (20.34% and 9.89%, respectively). The annual species (7 from 12) were concentrated mainly at the well group which was characterized by high water regime.

Group VI. It embraced five stand and twenty one species. This group occupied the Wadi bed of Wadi El-Fath. The leading dominant species of this group was *Tamarix aphylla* (I.V.=87.86), while the co-dominant species were *Retama raetam* (I.V.=53.06), *Haloxylon salicornicum* (I.V.=37.66), *Thymelaea hirsuta* (I.V.=28.76), *Fagonia arabica* (I.V.=21.04), *Zilla spinosa* (I.V.=13.39) and *Acacia raddiana* (I.V.=12.70). The highest mean values of fine sand and pH were recorded in soil supporting group VI with mean values 45.89% and 8.58 respectively, and also the lowest mean values of silt & clay 1.07%, E.C. 0.5 mmohs L^{1-} and Na^{+} 1.24 meq L^{1-}. Ahmed (1998) recorded that *T. aphylla* dominanted the delta of Wadi El-Fath. The

Wadi bed of Wadi El-Fath characterized by the presence of undulating sand sheets or scattered movable sand dunes, *T. aphylla – R. raetam* which dominated the Wadi bed, growing in distantly spaced patches form huge hummocks by which the plant is able to overcome the fluctuation of rainfall and drought value.

Group VII. It contained two stands and twenty two species. This group inhabited the small rocky hills of Wadi El-Fath. The leading dominant species of this group was *Zygophyllum dumosum* (I.V.=76.42), while the co-dominant species were *Lycium shawii* (I.V.=37.27), *Thymelaea hirsuta* (I.V.=19.41), *Haloxylon salicornicum* (I.V.=18.03), *Fagonia indica* (I.V.=14.29). *Ochradenus baccatus* (I.V.=12.92), *Cornulaca monocantha* (I.V.=11.25) and *Urginea maritima* (I.V.=11.00). The highest mean value of very fine gravel soil content was found in stands representing group VII with mean value 27.98%, and the lowest mean values of very coarse sand 2.13%, coarse sand 3.08%, medium sand 4.94%, Ca^{2+} 0.6 meq L^{1-}, Mg^{2+} 0.1 meq L^{1-} and $SO_4{}^{2-}$ 0.07 meq L^{1-}. Hills were covered in some areas by sand sheets which were suitable for growing of some species as *Stipagrostis plumosa*.

Group VIII. This group consisted of three stands and twenty species. This group inhabited the sides of the asphalt road that cutting Wadi El-Fath at the end of the downstream. The leading dominant species of this group was *Artemesia monosperma* (I.V.=91.06), while the co-dominant species were *Hyoscyamus muticus* (I.V.=35.66), *Zygophyllum coccineum* (I.V.=29.49), *Fagonia arabica* (I.V.=18.73), *Cornulaca monocantha* (I.V.=16.97), *Haloxylon salicornicum* (I.V.=16.87) and *Stipagrostis plumosa* (I.V.=15.64). The mean soil physicochemical parameters in this group showed that K^{+} attained the minimum value of 0.22 meq L^{1-}. *A. monosperma* is characteristic for sandy formations of north Sinai (Ahmed, 1998). This group represented favourable microhabitats for the vegetation near the road due to asphalt road don't absorb water after the rainfall and this water run-off on the two sides of the road increasing available water for the plant species near the road.

Wadi El-Fath was divided into four groups (V, VI, VII and VIII) each group represented different habitat namely: the well, Wadi bed, hills and sides of the asphalt road, respectively.

Physical and chemical analysis indicated that soils in the different groups of the two selected Wadis were calcareous and sandy. The pH was slightly alkaline. Moisture content in Wadi El-Fath was higher than Wadi

Nukhul in winter. Also soil texture showed variations between the two Wadis, soil of Wadi Nukhul was mainly medium sand. On the other hand soil of Wadi El-Fath was mainly fine sand. Physical variations between the two Wadis showed that Wadi El-Fath exhibited richer vegetation and higher species richness than Wadi Nukhul. Species were restricted to habitat with high water content and fine grained particles. Wadi El-Fath has moderate groundwater potentiality (Mohamed, 1997 and Khaled 2000) and this explain why most of the vegetation of this Wadi was vigor and most of species reached to the fruiting state rapidly than the vegetation of Wadi Nukhul.

Table (4). Characterization of the vegetational groups resulting from TWINSPAN.

	I	II	III	IV	V	VI	VII	VIII
No. of stands	2	2	4	2	1	5	1	3
No. of species	2	10	24	9	18	21	22	20
Soil parameter								
Very fine gravel %	22.02 ±0.28	2.23 ±0.17	7.45 ±2.71	4.80 ±2.40	4.23	3.17 ±2.71	27.98	10.98 ±6.14
Very coarse sand %	11.69 ±1.37	4.40 ±1.34	11.54 ±0.63	10.64 ±1.15	4.52	5.03 ±4.54	2.13	6.85 ±2.14
Coarse sand %	10.39 ±0.63	9.30 ±3.11	18.39 ±2.22	18.40 ±1.13	7.72	10.89 ±10.92	3.08	8.94 ±1.11
Medium sand %	10.33 ±0.98	46.00 ±5.09	38.39 ±2.40	44.93 ±1.41	14.67	27.81 ±2.66	4.94	26.52 ±2.04
Fine sand %	13.81 ±3.10	30.65 ±7.07	17.61 ±1.77	18.10 ±2.83	33.94	45.89 ±17.61	26.98	33.23 ±3.94
Very fine sand %	15.04 ±2.55	6.26 ±2.81	5.18 ±1.46	2.10 ±0.31	27.89	6.15 ±0.74	25.42	10.81 ±2.63
Silt & Clay %	16.76 ±3.78	1.16 ±0.76	1.44 ±0.26	1.03 ±0.11	7.03	1.07 ±0.29	9.47	2.67 ±0.79
pH	7.43 ±0.20	8.36 ±0.16	8.27 ±0.23	8.35 ±0.09	8.02	8.58 ±0.30	8.03	8.02 ±0.01
E.C. mlmohs L^{1-}	12.51 ±2.14	1.00 ±0.21	5.98 ±5.02	0.23 ±0.03	3.96	0.50 ±0.62	0.81	1.27 ±0.42
Na meq L^{1-}	156.50 ± 0.31	7.04 ±1.44	63.00 ±69.76	0.63 ±0.31	31.80	1.24 ±0.35	12.10	5.23 ±6.99
K meq L^{1-}	14.79 ±5.96	1.46 ±0.47	0.81 ±0.52	0.23 ±0.06	1.40	0.27 ±0.05	0.44	0.22 ±0.04
Ca meq L^{1-}	15.50 ±0.71	1.40 ±0.38	25.41 ±9.23	1.2 ±0.40	4.20	2.42 ±2.73	0.60	7.83 ±2.89
Mg meq L^{1-}	26.25 ±9.55	1.30 ±0.34	3.58 ±2.04	0.5 ±0.07	1.30	0.63 ±1.02	0.10	1.13 ±0.29
HCO3 meq L^{1-}	10.15 ±3.75	0.60 ±0.20	0.90 ±0.20	1.00 ±0.14	1.90	1.24 ±0.15	2.00	1.60 ±0.17

Cl meq L^{1-}	121.88 ±2.10	7.50 ±1.63	41.35 ±45.50	0.75 ±0.31	40.00	1.85 ±1.56	6.75	21.67 ±5.77
SO4 meq L^{1-}	10.83 ±2.94	0.31 ±0.14	3.75 ±1.74	0.15 ±0.01	2.69	0.42 ±0.75	0.07	0.27 ±0.29
CaCO3 %	40.75 ±1.10	26.10 ±4.24	19.23 ±7.37	3.50 ±0.21	25.29	13.23 ±5.56	14.71	16.77 ±2.31
Moisture of winter %	0.28 ±0.04	0.18 ±0.03	0.36 ±0.19	0.25 ±0.06	20.34	16.27 ±2.04	16.72	18.10 ±0.87
Moisture of summer %	0.15 ±0.01	0.13 ±0.04	0.11 ±0.07	0.14 ±0.03	9.89	0.26 ±0.25	0.42	0.32 ±0.03
Species								
Acacia raddiana	—	—	6.05 ±4.95	97.73 ±11.80	14.68	12.70 ±19.63	—	—
Achillea fragrantissima	—	—	—	—	—	2.76 ±6.18	—	—
Achillea santolina	—	—	—	—	—	—	—	4.76 ±8.25
Alhagi graecorum	—	—	—	—	8.68	—	—	—
Anabasis articulata	—	—	1.39 ±2.78	—	—	—	—	—
Anabasis setifera	—	33.48 ±25.14	24.09 ±3.18	—	—	—	—	—
Andrachne aspra	—	—	—	—	—	3.00 ±4.43	4.49	—
Artemesia monosperma	—	—	—	—	9.91	5.35 ±6.05	—	91.06 ±59.50
Asparagus stipularis	—	—	—	—	—	—	8.90	—
Atreplix leucoclada	—	15.91 ±6.03	13.40 ±4.34	—	—	—	—	—
Capparis sinaica	95.76 ±135.4	—	—	—	—	—	—	—
Capparis spinosa	204.24 ±135.4	—	15.72 ±12.53	—	—	—	—	—
Citrullus colocynthis	—	—	2.21 ±4.42	3.70 ±5.23	—	—	—	—
Cleome droserifolia	—	—	11.91 ±4.40	7.71 ±1.50	—	—	—	—
Convolvulus arvensis	—	—	—	—	8.25	—	—	—
Convolvulus lanatus	—	—	—	—	—	—	—	14.93 ±2.24
Cornulaca monocantha	—	—	—	—	8.51	1.89 ±4.23	11.25	16.97 ±1.97
Crotalaria aegyptiaca	—	5.09 ±7.20	—	—	—	—	—	—
Cynodon dactylon	—	—	—	—	8.54	—	—	—
Echinops spinosus	—	—	—	—	—	—	10.42	2.02 ±3.49
Erodium crassifolium	—	—	—	—	—	—	9.04	4.24 ±7.34

Euphorbia retusa	—	—	—	—	10.05	—	—	2.12 ±3.67
Fagonia arabica	—	7.48 ±10.58	3.60 ±4.68	4.28 ±6.05	—	21.04 ±9.76	5.15	18.73 ±3.73
Fagonia indica	—	—	—	—	—	—	14.29	—
Fagonia mollis	—	—	2.91 ±5.82	—	—	—	—	9.61 ±1.62
Farsetia aegyptia	—	—	—	—	22.84	—	8.44	—
Gymnocarpos decander	—	—	1.95 ±3.89	—	—	1.70 ±2.46	10.30	—
Haloxylon salicornicum	—	130.45 ±62.74	56.86 ±44.23	93.56 ±15.55	52.57	37.66 ±33.11	18.03	16.87 ±14.77
Heliotropium arbainese	—	—	2.25 ±4.50	—	6.54	3.10 ±2.83	4.98	—
Hyoscyamus muticus	—	—	—	—	—	—	—	35.66 ±19.54
Iphiona mucronata	—	—	1.19 ±2.38	—	—	—	—	—
Launaea nudicaulis	—	—	—	—	—	—	6.37	—
Lycium shawii	—	—	—	—	—	1.70 ±3.80	37.27	—
Moricandia nitens	—	—	—	—	—	—	—	1.99 ±3.45
Nitraria retusa	—	—	1.51 ±3.01	—	—	—	—	2.09 ±3.63
Noaea mucronata	—	—	—	—	—	—	4.65	—
Ochradenus baccatus	—	32.69 ±7.51	13.61 ±11.59	47.75 ±24.45	10.40	3.97 ±3.68	12.92	—
Panicum turgidum	—	—	—	4.43 ±6.27	—	5.30 ±3.24	—	13.17 ±5.76
Paronychia arabica	—	—	—	—	—	—	4.52	2.07 ±3.58
Peganum harmala	—	—	—	—	26.21	7.68 ±6.44	—	—
pergularia tomentosa	—	—	—	—	8.97	2.21 ±3.04	—	—
Phrgmites australis	—	—	—	—	11.44	—	—	—
Pulicaria undulata	—	—	1.07 ±2.13	—	—	1.39 ±3.10	—	—
Reaumuria hirtella	—	13.44 ±19.00	7.18 ±5.95	—	—	—	—	—
Retama raetam	—	—	9.12 ±18.23	12.72 ±17.99	17.48	53.06 ±14.31	6.65	7.63 ±13.22
Salsola tetrandra	—	28.97 ± 3.59	5.39 ± 3.94	—	—	—	—	—
Stipagrostis plumosa	—	—	—	—	—	1.57 ±3.50	8.38	15.64 ±13.54

Suaeda vermiculata	—	13.57 ±19.20	3.16 ±3.80	—	—	—	—	—
Tamarix aphylla	—	—	—	—	—	87.86 ± 76.34	—	2.51 ± 4.35
Tamarix nilotica	—	—	49.80 ±37.12	—	8.54	—	—	—
Thymelaea hirsuta	—	—	—	—	14.37	28.76 ±25.36	19.41	8.44 ±14.62
Urginea maritima	—	—	—	—	—	—	11.00	—
Zilla spinosa	—	18.93 ±1.87	11.38 ±7.81	28.12 ±11.31	52.03	13.39 ±4.13	7.15	—
Zygophyllum album	—	—	1.96 ±3.92	—	—	—	—	—
Zygophyllum coccineum	—	—	52.32 ±24.90	—	—	3.92 ±3.80	—	29.49 ±51.08
Zygophyllum dumosum	—	—	—	—	—	—	76.42	—
Biodiversity indices								
Species richness	1.00 ±0.71	5.00 ±1.41	6.00 ±4.99	4.50 ±0	18.00	4.20 ±3.85	22.00	6.67 ±5.29
Species turnover	2	2	4	2	1	5	1	3
Shannon (H)	0.63 ±0.46	1.85 ±0.43	2.53 ±0.44	1.65 ±0.04	2.64	2.28 ±0.35	2.71	2.42 ±0.44
Simpson (D)	0.56 ±0.33	0.23 ±0.15	0.11 ±0.07	0.24 ±0.01	0.09	0.15 ±0.09	0.10	0.13 ±0.08

2.2. Ordination

The relations between vegetation structure along the two studied Wadis and environmental variables were examined by using CCA ordination program. This program produces two different biplots for each transect. The first biplot reflects the relationships between the different vegetational groups as previously identified by TWINSPAN classification program and the environmental factors, while the second biplot reveals the relationships between the recorded species along the two Wadis and the environmental factors.

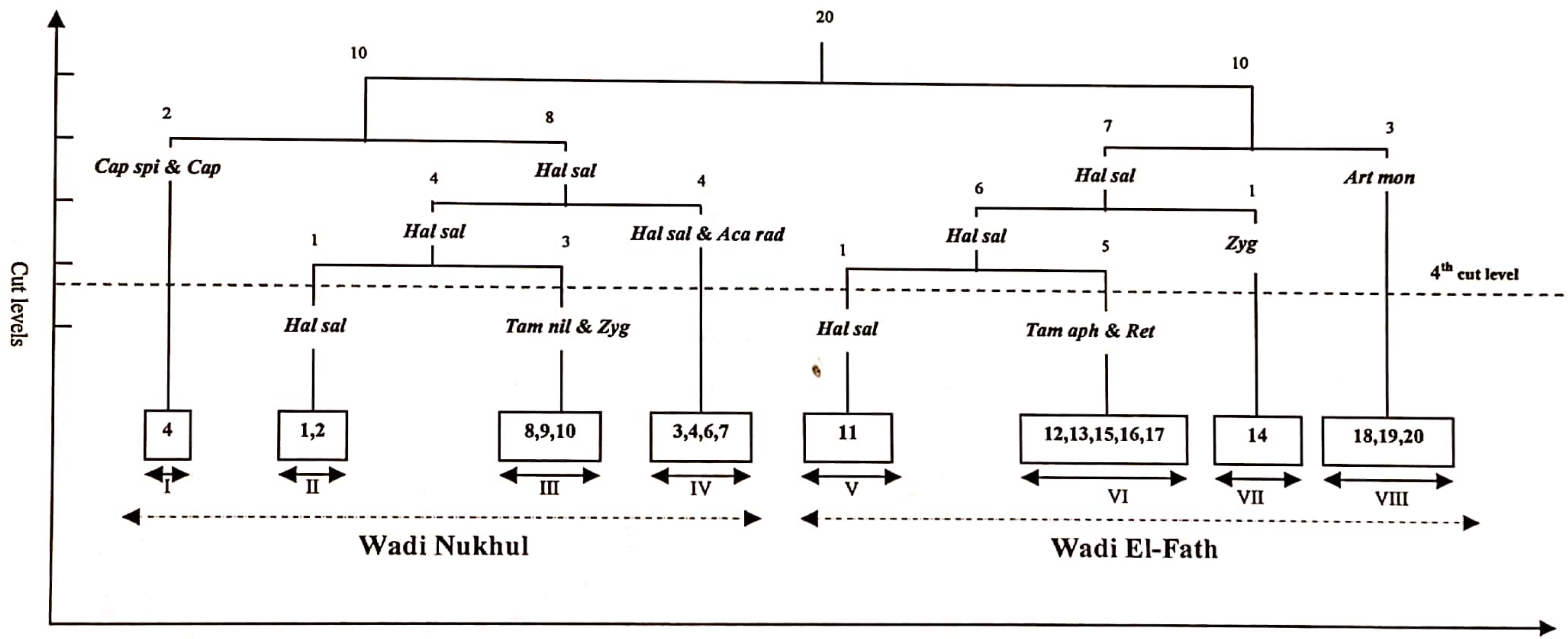
a. Biplot of the vegetational groups (Fig. 4a), showed that stand of vegetational group I was closely associated with most of chemical properties of soil. Similarly, the stands of vegetational groups II, III and IV showed a strong relationship with coarse sand and medium sand fraction. Group V was closely associated with pH. On the other hand, stands of the vegetational Group VI showed a close association with moisture in summer %. Whereas, stands of vegetational group VIII were clearly related to moisture in winter %. Finally, the stand of vegetational group VII showed a strong relationship with very fine sand fraction.

The first biplot showed that Wadi Nukhul (I, II, III and IV) affected by soil chemical properties and Wadi El-Fath (V, VI, VII and VIII) affected by physical properties of soil (Fig. 4a).

b. Biplot of the species (Fig. 4b). This biplot reveals that *Capparis spinosa* is associated with more than one chemical environmental variable. While, several species showed close association with coarse and medium sand fraction. Among them *Haloxylon salicornicum*, *Acacia raddiana*, *Anabasis setifera*, *Atriplex leucoclada*, *Salsola tetrandra*, *Cleome droserifolia*, *Ochradenus baccatus*, *Reaumuria hirtella* and *Tamarix nilotica*. Other species showed clear association pattern with pH of soil. Of these species *Peganum harmala*, *Zygophyllum coccineum* and *Phragmites australis*. While, several species as *Retama raetam*, *Tamarix aphylla* and *Heliotropium arbainense* showed relation to moisture in summer (summer moisture). On the other hand moisture in winter showed association with several species such as *Artemesia monosperma*, *Hyoscyamus muticus* and *Stipagrostis plumosa*. Other species showed clear association pattern with very fine sand fraction. Of these species *Zygophyllum dumosum*, *Urginea maritima* and *Gymnocarpos decander*.

The second biplot (Fig. 4b) revealed that soil texture and moisture content were the most important edaphic factors effect on the distripution of the recorded xerophytic plant species in the two studied Wadis this result agreed with Jafari *et al*. (2004).

Application of TWINSPAN and CCA techniques on the stands of Wadi Nukhul and Wadi El-Fath showed that the most nearest group from Wadi El-Fath to Wadi Nukhul was group V which dominated by *Haloxylon salicornicum* and inhabited near the well of El-Fath Village. Girgis and Ahmed (1985), recorded in the wet years a few springs were presented in the downstream part of Wadi Nukhul and these were associated with an oasis type of vegetation formed of *Tamarix nilotica, Juncus rigidus, Phragmites australis* and *Alhagi graecorum*. a high dissimilarity between vegetational group I that inhabited the bounding sides of Wadi Nukhul which had not any human effect on it and vegetatioal group VIII that inhabited near the asphalt road in Wadi El-Fath and had indirect human effect on it by constructing the roads. Groups II, III and IV represented the same habitat and this was recognized from CCA diagram which showed that groups II, III and IV were similar and located near each others between the arrows of coarse and medium sand fractions.



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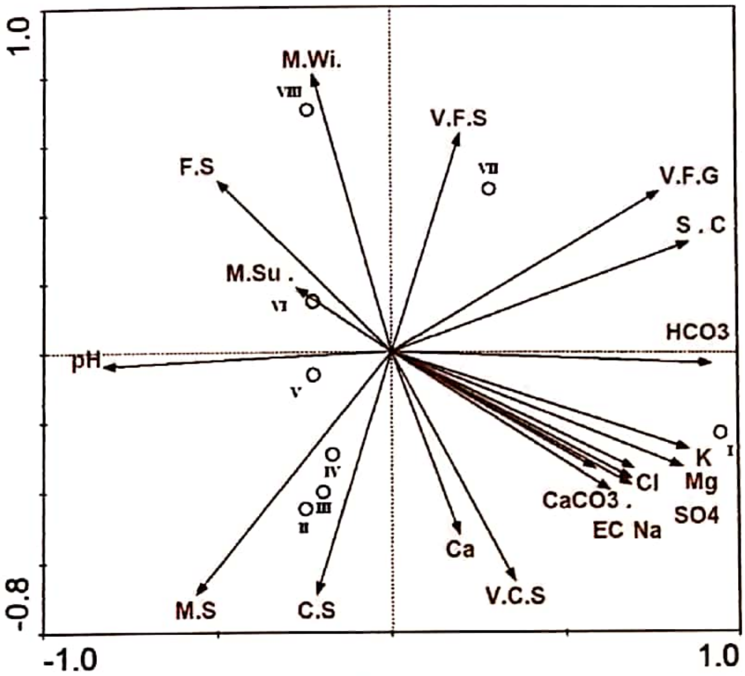

Figure (4a). Biplot of Canonical Correspondence Analysis showing the relationships between the eight vegetational groups of the two studied Wadis and the physicochemical parameters of soil.

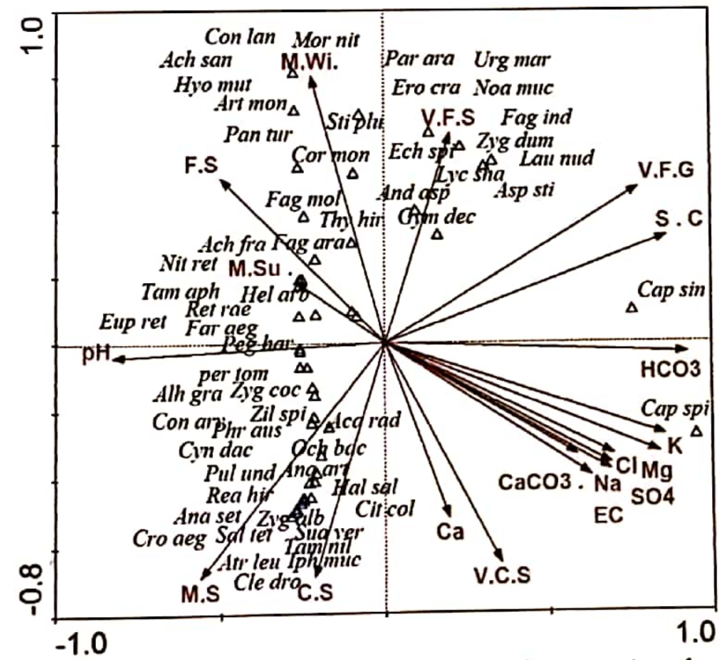

Figure (4b). Biplot of Canonical Correspondence Analysis showing the relationships recorded species in the two studied Wadis and the physicochemical parameters of soil. Species names are abbreviated to the first three letters of genus and species.

3. Diversity indices

Any vegetation in a particular place is influenced by the prevailing environmental factors including: climate, topography, soil, human activities and other biotic factors (Zahran, 1982). Species biodiversity indices had been used to characterize the plant communities. Concerning the species richness, it was clear that the vegetational group VII attained the maximum mean value 22.00, while the vegetational group I recorded the minimum one 1.00±0.71. The highest value for Species turnover was recorded in the vegetational group VI 5.00. On the other hand, vegetational group V and VII recorded the lowest value 1.00. Regarding both relative evenness (Shannon index) and relative concentration of dominance (Simpson index), vegetational group VII recorded the highest value 2.71 for Shannon index and the lowest value for Simpson index 0.09 recorded in group V, while vegetational group I attained the highest value for Simpson index 0.56±0.33 and the lowest value for Shannon index 0.63±0.46. Biodiversity indices (Table 4) revealed that the highest species diversity was found at hills habitat in Wadi El-Fath. While, bounding sides of Wadi Nukhul represent the lowest species diversity. Generally Wadi El-Fath was more diverse than Wadi Nukhul.

In addition to the well-known fact that desert vegetation is continuously exposed to the full impact of extreme and drastic environmental conditions, vegetation in the study area is subject to human impacts. The effects of man may be direct on the vegetation or indirect through their influence on the other components of the ecosystem. Human activities destroyed the vegetation of Wadi Nukhul especially by using this narrow Wadi as paved road used by trailer and long vehicles to reach the quarries. According to this, species number that were recorded in Wadi Nukhul decreased from about 77 species "44 perennials and 33 annuals" (Girgis and Ahmed, 1985) to 28 species. Off-road driving has long been recognized as a major deleterious factor, causing widespread damage to the vegetation and producing tracks on the soil surface (Adams *et al.*, 1982). Apart from the obvious damage to shrubs, vegetation is also affected due to soil compaction in tracks (Lovich and Bainbridge, 1999). Soil compaction reduces the ability of the soil to hold water and decreases the soil-gas volume (Rundel and Gibson, 1996). On the other hand human activities were positively effect on the vegetation of Wadi El-Fath and this appeared in the vegetation near the well of El-Fath village and near the asphalt road in the downstream of this Wadi. Deserts and semi-deserts are highly susceptible to disruption by a variety of external factors, particularly human impact (Rundel & Gibson, 1996).

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