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Vegetation spatial heterogeneity in a hyper arid Biosphere Reserve area in north Africa

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Ninety eight species of angiosperms belonging to 34 families were identified in the Wadi Allaqi Biosphere Reserve (S. E. Egypt): 33.7 % annuals and 66.3 % perennials. The members of Leguminosae contributed 19.4% of the total flora, considering the most dominant family in Wadi Allaqi. Three herbaceous species were recorded for the first time in this region: *Iphiona scabra*, *Chenopodium album* and *Lotus deserti*. Eight vegetation clusters were obtained and categorized into 4 distinct groups according to soil composition and chemical characteristics (concentration of bicarbonates, calcium, magnesium and chlorides), and intensity of inundation by the water of Lake Nasser.

Key words: Vegetation, *Tamarix*, *Iphiona scabra*, *Chenopodium album*, *Lotus deserti,* scrubland, life form, diversity, desert, Wadi Allaqi, Egypt

Introduction

Wadis represent one of the most prominent desert landforms, which exhibit physiographic irregularities that lead to parallel variations in species distribution (KASSAS and GIRGIS 1964). Wadi vegetation in the Eastern Desert of Egypt is distinguished into plant communities where the dominant perennial species give the permanent character to the plant cover in each habitat (KASSASS and IMAM 1954). This may be attributed to the scanty rainfall, which is not adequate for the appearance of many annuals. This desert lies in the Saharo-Sindian region and is bounded from the south by Sudano-Zambezian region; it is dominated by Saharo-Sindian species (OZENDA 1958). The South Eastern part belongs to the Saharo-Arabian phytogeographical region. In general, the vegetation is characterized by sparseness of plant cover and the preponderance of a limited number of plant species (SPRINGUEL et al. 1997). The life form distribution is closely correlated with topography and landform (KASSAS and GIRGIS 1965, ZOHARY 1973, ORSHAN 1986). The composition of life forms expresses a typical desert flora, the majority of species being therophytes and

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chamaephytes. The South Eastern Desert of Egypt is interesting ecologically because of its physiographic variations and environmental gradients. Considerable efforts have been made towards the elucidation of vegetation – environmental relationships in its wadi ecosystems (KASSAS and IMAM 1954, 1959; BATANOUNY 1979; EL-SHARKAWI et al. 1987). Recently, the multivariate approach (HILL 1979a,b; DIGBY and KEMPTON 1987) has been used for the study of spatial distribution and classification of the desert vegetation of Wadi Allaqi (SPRINGUEL and SHEDED 1991, SHEDED 2002).

The present study aims at analyzing the vegetation of Wadi Allaqi, in the south eastern desert of Egypt, in order to depict the main vegetation types and to assess the role of the soil factors and human interference that influence the vegetation. On the other hand, it is also a diagnostic study to evaluate the recent situation of Wadi Allaqi vegetation in comparison with the previous studies (e.g. SPRINGUEL et al. 1991, ALI et al. 1997).

Study area

The Wadi Allaqi Biosphere Reserve is situated in the South-Eastern Desert of Egypt (i.e. Egyptian Nubian Desert), about 180 km south of Aswan, on the eastern side of Lake Nasser (22° and 23° N to 33° and 35° E). It forms one of the most extensive drainage systems in Egypt's Eastern Desert. Its upstream tributaries drain some of the mountains that divide the Red Sea coastal plain from the Nile Valley. The wadi extends for about 350 km, in a NW- SE direction. It has an average width of about 1 km being narrower upstream and considerably broader downstream as it approaches Lake Nasser (Fig. 1).

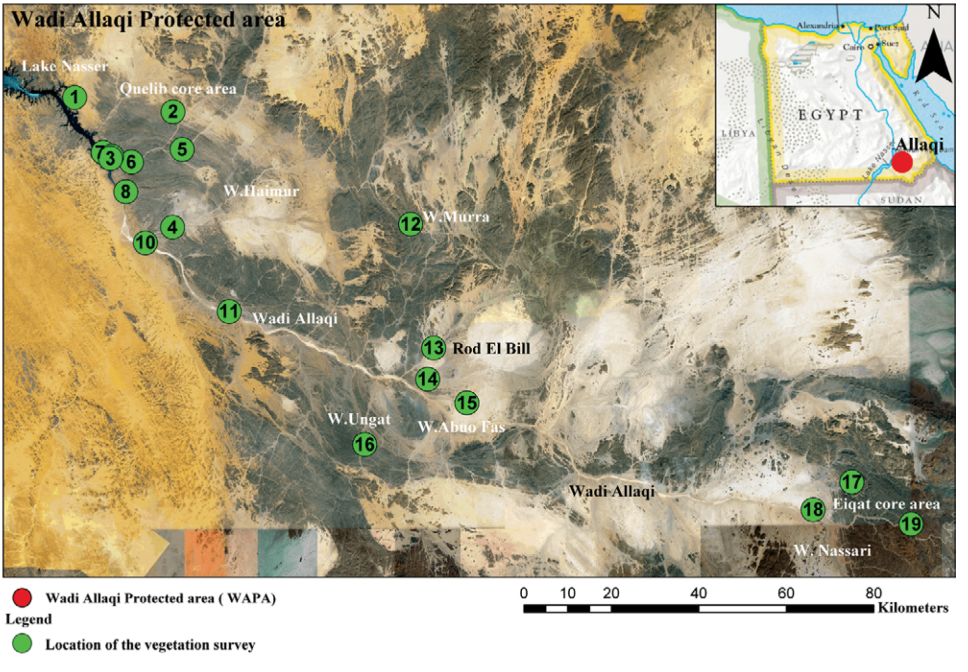

Fig. 1. Map of Wadi Allaqi showing the 19 sampled locations (1–19).

The main course of Wadi Allaqi starts in the area of Gabal Iss. It has a length of 350 km and runs generally west, reaching the Nile at Kurisku. The lower part of the wadi is now inundated by the water of Lake Nasser. The upstream part is ca 500 m. a.s.l. However the surrounding mountains are high; one such mountain is Gabal Eigat in the upstream part, rising to 1400 m. a.s.l. (BELAL and SPRINGUEL 1996). The upstream tributaries may receive occasional rainfall and their drainage may accumulate in the main channel of Wadi Allaqi forming torrents that are the main source of water in this wadi (KASSAS and GIRGIS 1969). The middle part of Wadi Allaqi on the north side receives large influents. Wadi Abu Murra is one of these influents and lays a more clearly defined channel bounded by high ground on both sides. Its channel was once a part of the main camel- caravan. Wadi Umm Raylan is another influent. It is smaller wadi, of about 30 km. with a few short effluent runnels (KASSAS and GIRGIS 1969).Wadi Allaqi consists of the El Quleib core area, an extreme arid ecosystem comprising a small number of plants and animals. Vegetation is sparse with *Acacia ehrenbergiana* and *Aerva javanica* as the characteristic species. The El Quleib core area is located in the downstream part of the reserve, and the Eigat core area is located in the upstream part of Wadi Allaqi in a remote area that is difficult to reach. The impacts of the local community include charcoal formation, collection of medicinal plants, grazing and cutting trees.

Soil in Wadi Allaqi consists of wadi fill deposits and varies in depth, physical and chemical composition depending on the soil-forming materials, transport processes and depositions (MOALLA and PULFORD 1991). Tamarix litter has an important effect on surface soils as it accumulates salts and increases soil salinity. The study area is characterized by a hyperarid environment with an aridity index of less than 0.05 (AYYAD and GHABBOUR 1986). Data from the Wadi Allaqi meteorological station between 1996 and 2005 shows the annual mean temperature is 25.8 °C. It can be as low as –2 °C in January. On the other hand, the mean maximum temperature of 41.8 °C has been recorded in July, which can often be as hote as 45 °C or higher, especially in August. The monthly mean relative humidity ranged between 14.0 and 38%, with an annual mean of 22.7%. The annual rainfall rarely exceeds 5 mm and is highly variable in both time and space. The wind speed at Aswan ranged between 4 and 8 km h^{-1} between 1960 and 1980 with an annual mean of 5.9 km h^{-1}. The annual fluctuation of water in Lake Nasser during a forty-year period (1964–2003), reached its first peak of 178 m. a.s.l. in 1978, but by 1988 the level had dropped to 154 m. a.s.l. and 175.6 in 2003 m. a.s.l. (Lake Nasser Authority).

Materials and methods

One hundred and twelve stands were analyzed at 19 locations within the Wadi Allaqi Biosphere Reserve (upstream, midstream and downstream parts, including the different wadi tributaries), in the period from November 2004 to May 2005. The locations and stands were selected to represent a wide range of physiographic and environmental variation in each tributary. In each location, sampling stands were situated randomly using the réléve method described by MULLER-DOMBOIS and ELLENBERG 1974). Species were identified after TACKHOLM 1974, BOULOS 1999, 2000 and 2002. Species life forms were determined depending upon the location of the regenerative buds and the shed parts during the unfavorable season (RAUNKIER 1934).

Soil samples were collected from each stand. Sizes of soil particles were estimated using the pipette method (KILMER and ALEXANDER 1949. Soil water extracts (1:5) were prepared for determination of EC and pH using conductivity and pH meters, chlorides by direct titration against silver nitrate using potassium chromate as an indicator, carbonates and bicarbonates by direct titration against HCl using phenolphthalein and methyl orange as indicators, calcium and magnesium by titration against EDTA (ethylenediamine dihydrogen tetraacetic acid) using ammonium purpurate and eriochrome black T as indicators (JACKSON 1977).

Two-way indicator species analysis (Twinspan), as a classification technique and detrended correspondence analysis (DCA) as an ordination technique, were applied to the presence estimates of 98 species in 112 vegetation stands according to the computer programs of HILL (1979 a, b). The relationship between the vegetation and edaphic variables were assessed by calculating the simple linear correlation coefficient (r) between the DCA axes (reflect the vegetation gradient) and the soil variables.

Results

Stand classification according to TWINSPAN led to the identification of 8 clusters of stands similar in terms of their species composition (Fig 2); they are named after the dominant species as follows: *Balanites aegyptiaca – Acacia tortilis* subsp. *tortilis*, *Fagonia indica – Leptadenia pyrotechnica – Acacia tortilis* subsp. *tortilis – Solenostemma arghel*, *Acacia ehrenbergiana – Morettia philaeana*, *Acacia ehrenbergiana – Aerva javanica –*

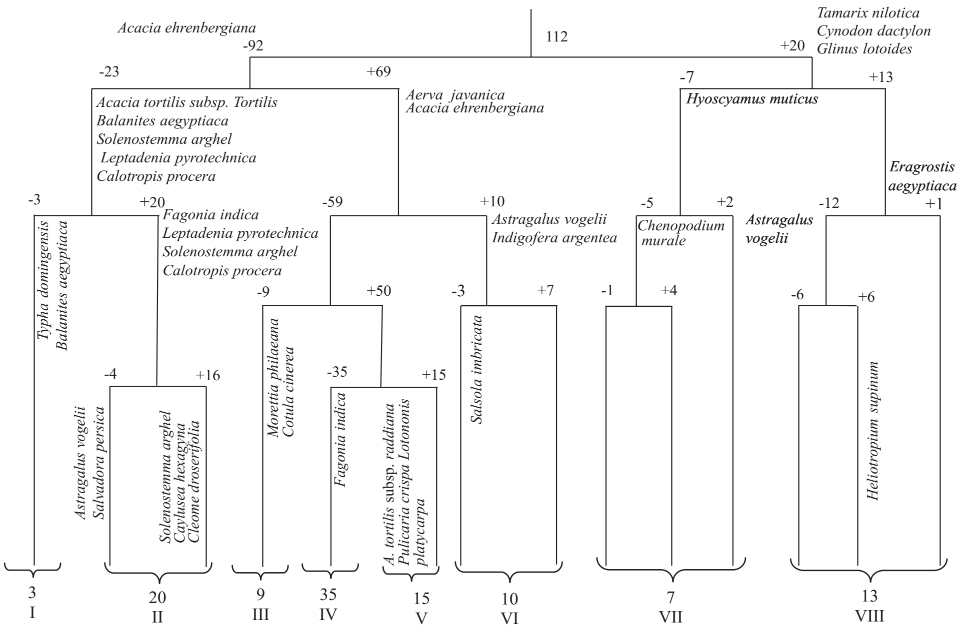

Fig. 2. Dendrogram indicating the eight vegetation clusters resulting from the TWINSPAN classification of the 112 sampled vegetation stands in Wadi Allaqi.

Fagonia indica, *Acacia ehrenbergiana – Aerva javanica*, *Acacia ehrenbergiana – Indigofera argentea, Hyoscyamus muticus – Tamarix nilotica – Morettia philaeana- Glinus lotoides* and *Tamarix nilotica – Glinus lotoides – Cynodon dactylon* (Tab. 1, Fig. 2).

Ninety-eight species recorded in the present study belonging to 34 families and 74 genera (Tab. 4). 33 species are annuals (33.7%) and 65 perennials (66.3%). Members of Leguminosae contribute 19.4% of the total flora and so considered the most dominant family, followed by Gramineae (13.3%), Zygophyllaceae (6.1%) and Compositae (6.1%). Three herbaceous species were recorded for the first time in this region: *Iphiona scabra* and *Lotus deserti* at the upstream part, and *Chenopodium album* the downstream.

Tab. 1. Floristic composition of the vegetation clusters (I–VIII) identified after the application of TWNISPAN on the 112 sampled stands in Wadi Allaqi. * New recorded species in Wadi Allaqi. The figures represent presence value.

	Cluster								
	I	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**P%**
Number of stands per cluster	**3**	**20**	**9**	**35**	**15**	**10**	**7**	**13**	
Species present in seven clusters									
Acacia ehrenbergiana	0.0	10.0	88.9	100.0	100.0	100.0	14.3	7.7	64.3
Species present in six clusters									
Aerva javanica	0.0	0.0	66.7	94.3	100.0	20.0	57.1	46.2	58.9
Species present in five clusters									
Faidherbia albida	33.3	10.0	11.1	0.0	0.0	0.0	14.3	7.7	5.4
Balanites aegyptiaca	100.0	40.0	11.1	0.0	13.3	0.0	14.3	0.0	13.4
Fagonia indica	0.0	70.0	66.7	94.3	6.7	0.0	42.9	0.0	50.9
Pulicaria crispa	0.0	0.0	22.2	2.9	40.0	0.0	42.9	15.4	12.5
Species present in four clusters									
Acacia tortilis subsp. *raddiana*	0.0	50.0	11.1	11.4	66.7	0.0	0.0	0.0	22.3
Astragalus vogelii	0.0	0.0	11.1	0.0	0.0	40.0	28.6	7.7	7.1
Salsola imbricata	0.0	5.0	0.0	0.0	13.3	30.0	42.9	0.0	8.0
Species present in three clusters									
Fagonia glutinosa	33.3	5.0	22.2	0.0	0.0	0.0	0.0	0.0	3.6
Senna alexandrina	0.0	20.0	44.4	8.6	0.0	0.0	0.0	0.0	9.8
Citrullus colocynthis	0.0	20.0	0.0	0.0	0.0	0.0	57.1	7.7	8.0
Glinus lotoides	0.0	5.0	0.0	0.0	0.0	0.0	57.1	76.9	13.4
Pulicaria incisa	0.0	5.0	33.3	0.0	0.0	0.0	14.3	0.0	4.5
Species present in two clusters									
Acacia tortilis subsp. *tortilis*	100.0	55.0	0.0	0.0	0.0	0.0	0.0	0.0	12.5
Cleome chrysantha	33.3	10.0	0.0	0.0	0.0	0.0	0.0	0.0	2.7
Chrozophora oblongifolia	33.3	5.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8
Crotalaria microphylla	33.3	10.0	0.0	0.0	0.0	0.0	0.0	0.0	2.7
Senna italica	0.0	20.0	11.1	0.0	0.0	0.0	0.0	0.0	4.5
Cotula cinerea	0.0	25.0	66.7	0.0	0.0	0.0	0.0	0.0	9.8
Forsskalea tenacissima	0.0	10.0	22.2	0.0	0.0	0.0	0.0	0.0	3.6

Tab. 1. – continued

	Cluster								
	I	II	III	IV	V	VI	VII	VIII	P%
Number of stands per cluster	**3**	**20**	**9**	**35**	**15**	**10**	**7**	**13**	
Stipagrostis plumosa	0.0	5.0	44.4	0.0	0.0	0.0	0.0	0.0	4.5
Cynodon dactylon	0.0	0.0	0.0	0.0	0.0	0.0	28.6	61.5	8.9
Tamarix nilotica	0.0	0.0	0.0	0.0	0.0	0.0	85.7	84.6	15.2
Heliotropium supinum	0.0	0.0	0.0	0.0	0.0	0.0	14.3	46.2	6.3
Eragrostis aegyptiaca	0.0	0.0	0.0	0.0	0.0	0.0	28.6	7.7	2.7
Indigofera argentea	0.0	5.0	0.0	0.0	0.0	70.0	0.0	0.0	7.1
Cleome droserifolia	0.0	25.0	0.0	2.9	0.0	0.0	0.0	0.0	5.4
Reseda pruinosa	0.0	5.0	0.0	0.0	0.0	0.0	28.6	0.0	2.7
Haplophyllum tuberculatum	0.0	5.0	0.0	0.0	0.0	0.0	14.3	0.0	1.8
Psoralea plicata	0.0	0.0	11.1	0.0	0.0	0.0	14.3	0.0	1.8
Solenostemma arghel	0.0	55.0	0.0	0.0	0.0	0.0	14.3	0.0	10.7
Trichodesma africanum	0.0	5.0	0.0	0.0	0.0	0.0	14.3	0.0	1.8
Astragualus eremophilus	0.0	0.0	11.1	0.0	0.0	0.0	14.3	0.0	1.8
Morettia philaeana	0.0	0.0	88.9	0.0	0.0	0.0	57.1	0.0	10.7
Lotus sp	0.0	0.0	0.0	0.0	6.7	0.0	14.3	0.0	1.8
Species present in one clusters									
Euphorbia forsskalii	33.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9
Tribulus pentandrus	33.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9
Ziziphus spina-christi	33.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9
*Iphiona scabra**	33.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9
Euphorbia granulata	33.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9
Cleome paradoxa	33.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9
Lupinus digitatus	33.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9
Zilla spinosa	33.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9
Dipterygium glaucum	33.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9
Tribulus ochroleucus	33.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9
Typha domingensis	33.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9
Chrozophora tinctoria	33.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9
Aizoon canariense	0.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8
Anticharis glandulosa	0.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9
Aristida adscensionis	0.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9
Arnebia hispidissima	0.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9
Asphodelus fistulosus	0.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9
Calotropis procera	0.0	45.0	0.0	0.0	0.0	0.0	0.0	0.0	8.0
Caylusea hexagyna	0.0	25.0	0.0	0.0	0.0	0.0	0.0	0.0	4.5
Cistanche phelypaea	0.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9
Farsetia aegyptiaca	0.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9
Cymbopogon schoenanthus L. Spreng. subsp *proximus*	0.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8
Heliotropium pterocarpum	0.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9

Tab. 1. – continued

	Cluster								
	I	II	III	IV	V	VI	VII	VIII	P%
Number of stands per cluster	**3**	**20**	**9**	**35**	**15**	**10**	**7**	**13**	
Monsonia heliotropoides	0.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8
Zygophyllum simplex	0.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9
Dichanthium foevulatum	0.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9
Trianthema triquetra	0.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9
Leptadenia pyrotechnica	0.0	65.0	0.0	0.0	0.0	0.0	0.0	0.0	11.6
Lotus deserti *	0.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8
Maerua crassifolia	0.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9
Ochradenus baccatus	0.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9
Panicum turgidum	0.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8
Pergularia tomentosa	0.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9
Salvadora presica	0.0	20.0	0.0	0.0	0.0	0.0	0.0	0.0	3.6
Orobanche ramosa	0.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9
Cocculus pendulus	0.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9
Fagonia bruguieri	0.0	0.0	22.2	0.0	0.0	0.0	0.0	0.0	1.8
Capparis decidua	0.0	0.0	11.1	0.0	0.0	0.0	0.0	0.0	0.9
Heliotropium arbainense	0.0	0.0	22.2	0.0	0.0	0.0	0.0	0.0	1.8
Crotalaria aegyptiaca	0.0	0.0	0.0	2.9	0.0	0.0	0.0	0.0	0.9
Hyphaene thebaica	0.0	0.0	0.0	2.9	0.0	0.0	0.0	0.0	0.9
Lotononis platycarpa	0.0	0.0	0.0	0.0	40.0	0.0	0.0	0.0	5.4
Chenopodium murale	0.0	0.0	0.0	0.0	0.0	0.0	14.3	0.0	0.9
Hyoscyamus muticus	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	6.3
Rumex dentatus	0.0	0.0	0.0	0.0	0.0	0.0	42.9	0.0	2.7
Tephrosia purpurea	0.0	0.0	0.0	0.0	0.0	0.0	28.6	0.0	1.8
Cyperus laevigatus	0.0	0.0	0.0	0.0	0.0	0.0	28.6	0.0	1.8
Phragmites australis	0.0	0.0	0.0	0.0	0.0	0.0	28.6	0.0	1.8
Zea mays	0.0	0.0	0.0	0.0	0.0	0.0	14.3	0.0	0.9
Polycarpaea repens	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.7	0.9
Aristida mutabilis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.7	0.9
Sonchus oleraceus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.7	0.9
Acacia nilotica	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.7	0.9
Imperata cylindrica	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.7	0.9
Chenopodium album *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.7	0.9
Sesbania sesban	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.7	0.9
Abutilon pannosum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.4	1.8
Fimbristylis bis-umbellata	0.0	0.0	0.0	0.0	0.0	0.0	0.0	46.2	5.4
Crypsis schoenoides	0.0	0.0	0.0	0.0	0.0	0.0	0.0	46.2	5.4
Senecio flavus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.7	0.9
Ricinus communis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.7	0.9
Tamarix aphylla	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.7	0.9

Six life forms of species were recognized (Tab. 4, Fig. 3) phanerophytes (19 species), chamaephytes (22 species), hemicryptophytes (16 species), geophytes (4 species), parasites (2 species), helophytes (2 species) and therophytes (33 species). Regarding the floristic categories, only one species is a Mediterranean element (*Lupinus digitatus*) and another one is Saharo-Sindian with extension to the Mediterranean region (*Heliotropium supinum*). On the other hand, four species are cosmopolitan taxa: *Chenopodium album*, *Chenopodium murale*, *Crypsis schoenoides* and *Sonchus oleraceus* (Tab. 4, Fig. 4), while 30 species are Sudano-Zambezian with extension to Saharo-Sindian and 18 species belong to the Saharo-Sindian with extension to Sudano-Zambezian region. Three species belong to Saharo-Sindian with extension to Irano-Turanian (*Fagonia bruguieri, Haplophyllum tuberculatum* and *Hyoscyamus muticus*).

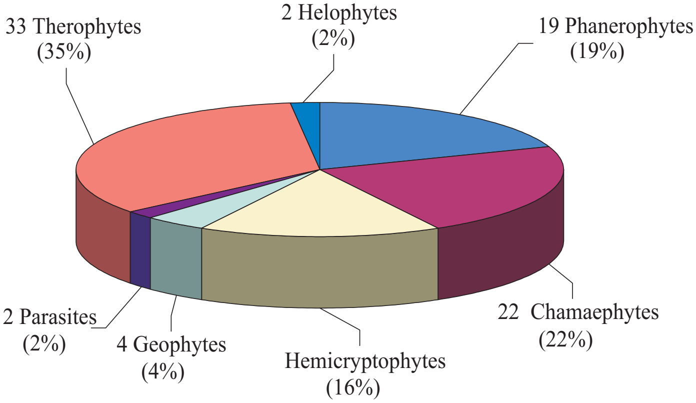

Fig. 3. Biological spectrum of Wadi Allaqi vegetation.

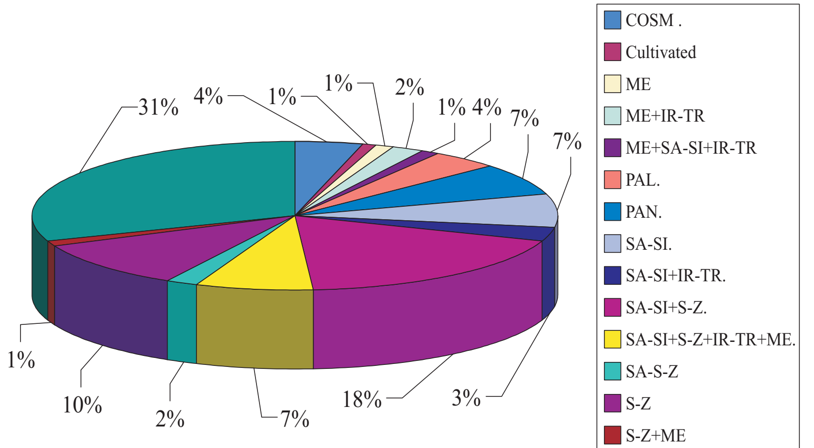

Fig. 4. Floristic category spectrum of Wadi Allaqi vegetation. COSM – Cosmopolitan, Pal – Palaeotropical, Pan – Pantropical, SA-SI – Saharo-Sindian, S-Z – Sudano-Zambezian, ME – Mediterranean and IR-TR – Irano-Turanian.

Sand attains the highest value in cluster I (85.5%) and the lowest in cluster VIII (87.4). Clay has the highest value in cluster VIII (8.1%) and the lowest in cluster III (1.9), while silt has the highest in cluster VIII (12.0) and the lowest in cluster II (10.7). The minimum value of pH is attained in cluster II and IV (7.4) and the maximum in clusters VI, VII and VIII (7.6). EC has a maximum in cluster VIII (413 mS^{-1}) and a minimum in cluster I (83.7 mS^{-1}). Cl attains the highest concentration in cluster VIII [16.0 mg (100 mg)$^{-1}$] and the lowest in cluster III [10.0 mg (100 mg)$^{-1}$]. HCO_3 has the highest value in cluster II [46 mg (100 mg)$^{-1}$] and the lowest in cluster IV [29 mg (100 mg)$^{-1}$]. Ca has a maximum in cluster VIII [20.7 mg (100 mg)$^{-1}$] and its minimum in cluster IV [9.1 mg (100 mg)$^{-1}$], while Mg attains a maximum in cluster VIII [14.6 mg (100 mg)$^{-1}$] and a minimum in cluster III [3.0 mg (100 mg)$^{-1}$]. Organic matter attains the highest in cluster VII (1.7 %) and the lowest in cluster I (0.8 %) (Tab. 2). The first DCA axis (AX1) correlated positively with electric conductivity (r = 0.81), calcium (r = 0.59), clay (r = 0.89) magnesium (r = 0.78) and organic matter (r = 0.76); and negatively with sand (r = –0.94). The third axis (AX3) correlated positively with silt (r = 0.76) (Tab. 3). The similarity between the vegetation clusters, as revealed by DCA analysis, shows a distinct pattern along the two-dimensional plane of axes 1 and 2 (using the mean vectors of centroids of each cluster): group of clusters I and II; cluster VI; group of clusters III, IV and V; and group of clusters VII and VIII.

Tab. 2. Means of soil characteristics of the eight vegetation clusters identified in Wadi Allaqi.

Cluster	pH	EC mS^{-1}	Physical characteristics: Silt	Clay	Total sand	Organic matter	Chemical characteristics: HCO_3	Cl	Ca	Mg
			%				mg (100 g)$^{-1}$			
I	7.5	83.7	11.5	2.5	85.5	0.8	42.4	13.7	12.1	2.7
II	7.4	105.3	10.7	2.4	85.1	1.1	46.3	11.9	11.4	4.1
III	7.5	122.9	11.0	1.9	85.1	1.2	34.6	10.0	12.2	3.0
IV	7.4	129.9	10.8	2.7	85.1	1.0	29.3	12.9	9.1	7.1
V	7.6	117.5	11.4	3.1	83.6	1.1	38.9	12.8	10.6	5.2
VI	7.6	108.1	10.9	3.4	84.2	1.0	38.0	12.2	13.4	3.2
VII	7.6	166.7	11.9	5.2	80.8	1.7	35.3	11.3	11.1	6.3
VIII	7.6	413.3	12.0	8.1	78.4	1.3	39.8	16.0	20.7	14.6

Discussion

Ninety-eight species were recorded in the present study compared with 127 species recorded by SPRINGUEL et al. (1991) in the same study area. This may be due to the severe environmental conditions as the area has been completely rainless since 1995/1996. Overexploitation of the plant resources (e.g. overgrazing and overcutting) may also responsible for the decrease of species diversity in this region (ALI et al. 2000). The common perennial species are: *Acacia ehrenbergiana*, *Aerva javanica*, *Fagonia indica*, *Acacia tortilis* subsp. *raddiana, Solenostemma arghel*, *Pulicaria crispa*, *Acacia tortilis* subsp. *tortilis*, *Calotropis procera*, *Morettia philaeana* and *Leptadenia pyrotechnica*. The common annuals are *Astragalus vogelii*, *Pulicaria incisa*, *Glinus lotoides*, *Indigofera argentea* and *Cotula*

Tab. 3. The species recorded in Wadi Allaqi and their families, floristic categories and life forms. COSM – Cosmopolitan, Pal – Palaeotropical, Pan – Pantropical, TR – Tropical, SA-SI – Saharo- Sindian, S-Z – Sudano-Zambezian, ME – Mediterranean, and IR-TR – Irano--Turanian. The life forms are Ph – phanerophyte, Ch – chamaephyte, H – hemicryptophyte, G – geophyte, He – helophyte, P – parasite, and Th – therophyte.

Species	Family	Floristic Category	Life form
Aerva javanica (Burm.f) Juss.ex Schult.	Amaranthaceae	SA-SI+S-Z.	Ch
Abutilon pannosum (G.Forst. f.) Schltdl.	Malvaceae	S-Z+SA-SI.	Ch
Faidherbia albida (Delile).	Leguminosae	S-Z	Ph
Acacia ehrenbergiana (Hayne).	Leguminosae	S-Z+SA-SI.	Ph
Acacia nilotica L. (Delile*)*	Leguminosae	S-Z	Ph
Acacia tortilis subsp. *raddiana* Savi	Leguminosae	S-Z+SA-SI.	Ph
Acacia tortilis subsp. *tortilis* (Forssk.) Hayne	Leguminosae	S-Z+SA-SI.	Ph
Aizoon canariense L.	Aizoaceae	S-Z+SA-SI.	Th
Anticharis glandulosa (Asch).	Scrophulariaceae	SA-SI+S-Z.	Th
Aristida adscensionis L.	Gramineae	PAN	Th
Aristida mutabilis (Trin. and Rupr.).	Gramineae	S-Z+SA-SI.	Th
Arnebia hispidissima (Lehm.) DC	Boraginaceae	S-Z+SA-SI.	Th
Asphodelus fistulosus Cav.	Liliacaae	ME+SA-SI+IR-TR	Th
Astragalus eremophilus Bioss	Leguminosae	SA-SI+S-Z.	Th
Astragalus vogelii (Webb) Bornm.	Leguminosae	SA-SI+S-Z.	Th
Balanites aegyptiaca (L.) Del.	Balanitaceae	S-Z+SA-SI.	Ph
Calotropis procera (Ait.)	Asclepiadaceae	SA-SI+S-Z.	Ph
Capparis decidua (Forssk.) Edgew	Capparaceae	S-Z+SA-SI.	Ph
Senna italica (Mill.).	Leguminosae	S-Z+SA-SI.	Ch
Senna alexandrina (Mill.).	Leguminosae	S-Z+SA-SI.	Ch
Caylusea hexagyna (Forssk.) M. L. Green	Resedaceae	S-Z+SA-SI.	Th
Chenopodium album L.	Chenopodiaceae	COSM.	Th
Chenopodium murale L.	Chenopodiaceae	COSM.	Th
Chrozophora obongifolia (Delile) Spreng.	Euphorbiaceae	S-Z.	Ch
Chrozophora tinctoria L.Raf.	Euphorbiaceae	S-Z+SA-SI.	Ch
Cistanche phelypaea (L.) Cout.	Orobanchaceae	SA-SI+S-Z+IR-TR+ME.	P
Citrullus colocynthis (L.) Schrad.	Cucurbitaceae	SA-SI+S-Z+IR-TR+ME.	H
*Cleome chrysantha.*Decne.	Cleomaceae	SA-SI.	Ch
Cleome droserifolia (Forssk.) Delile.	Cleomaceae	SA-SI+S-Z.	H
Cleome paradoxa DC.	Cleomaceae	S-Z.	H
Cocculus pendulus (J. R. and G. Forst.) Diels	Menispermaceae	S-Z+SA-SI.	Ph
Cotula cinerea Del.	Compositae	SA-SI.	Th
Crotalaria aegyptiaca Benth.	Leguminosae	SA-SI+S-Z.	H
Crotalaria microphylla Vahl	Leguminosae	S-Z.	Th
*Crypsis schoenoides (*L)Lam	Gramineae	COSM.	Th
Cymbopogon schoenanthus L. Spreng. subsp *proximus* A.Rich	Gramineae	SA-SI.	G
Cynodon dactylon (L.) Pers	Gramineae	PAN.	G

Tab. 3. – continued

Species	Family	Floristic Category	Life form
Cyperus laevigatus L.	Cyperaceae	PAN.	G
Dichanthium foevulatum Delile.	Gramineae	SA-SI+S-Z+IR-TR+ME.	H
Dipterygium glaucum Decne.	Cruciferae	S-Z.	Ch
Eragrostis aegyptiaca (Willd.) Delile.	Gramineae	S-Z.	Th
Euphorbia forsskalii J. Gay.	Euphorbiaceae	S-Z+SA-SI.	Th
Euphorbia granulata Forssk.	Euphorbiaceae	S-Z+SA-SI.	Th
Fagonia bruguieri DC.	Zygophyllaceae	SA-SI+IR-TR.	H
Fagonia glutinosa Delile	Zygophyllaceae	SA-SI.	H
Fagonia indica Burm.f.	Zygophyllaceae	SA-SI+S-Z.	Ch
Farsetia aegyptiaca	Cruciferae	S-Z+SA-SI.	Ch
Fimbristylis bis-umbellata (Forssk) Bubani.	Cyperaceae	PAL.	Th
Forsskalea tenacissima L.	Urticaceae	SA-SI+S-Z.	H
Glinus lotoides L.	Molluginaceae	PAL.	Th
Haplophyllum tuberculatum (Forssk.). Juss	Rutaceae	SA-SI+IR-TR.	Ch
Heliotropium arbainense (Fresen.)	Boraginaceae	SA-TR+-S-Z	Ch
Heliotropium pterocarpum Hochst	Boraginaceae	SA-TR+-S-Z	Th
*Heliotropium supinum (*L.)	Boraginaceae	S-Z+ME	Th
Hyoscyamus muticus (L.)	Solanaceae	SA-SI+IR-TR.	Ch
Hyphaene thebaica (L.) Mart.	Palmae	S-Z.	Ph
Imperata cylindrica L.	Gramineae	PAN.	H
Indigofera argentea (Burm.)	Leguminosae	S-Z+SA-SI.	H
Iphiona scabra DC.	Compositae	SA-SI+S-Z.	Ch
Leptadenia pyrotechnica (Forssk.) Decne	Asclepiadaceae	S-Z+SA-SI.	Ph
Lotononis platycarpa (Viv.) Pic Serm.	Leguminosae	S-Z+SA-SI.	Th
Lotus sp. L.	Leguminosae	S-Z+SA-SI.	Th
Lotus deserti Tackh. et Boulos	Leguminosae	SA-SI.	H
Lupinus digitatus Forssk.*ssp orientalis* sensu. Täckh.	Leguminosae	ME.	Th
Maerua crassifolia (Forssk.)	Capparaceae	S-Z.	Ph
*Monsonia heliotropoides (*Cav.) Boiss.	Geraniaceae	SA-SI+S-Z.	H
Morettia philaeana (Del.) DC.	Cruciferae	SA-SI+S-Z.	H
Ochradenus baccatus Del.	Resedaceae	SA-SI+S-Z.	Ph
Orobanche ramosa L.	Orobanchaceae	ME+IR-TR	P
Panicum turgidum (Forssk.)	Gramineae	SA-SI+S-Z+IR-TR+ME	G
Pergularia tomentosa L.	Asclepiadaceae	S-Z+SA-SI.	Ch
Phragmites australis (Cav.)Trin ex Steud	Gramineae	PAL.	He
Polycarpaea repens (Forssk.) Asch. et Schweinf.	Caryophyllaceae	SA-SI+S-Z.	H
Psoralea plicata Delile	Leguminosae	SA-SI+S-Z.	Ch
Pulicaria crispa (Forssk.) Oliv.	Compositae	S-Z+SA-SI.	Ch
Pulicaria incisa (Lam.) DC.	Compositae	S-Z+SA-SI.	H

Tab. 3. – continued

Species	Family	Floristic Category	Life form
Reseda pruinosa (Delile)	Resedaceae	SA-SI	Th
Ricinus communis L.	Euphorbiaceae	PAN.	Ch
Rumex dentatus L.	Polyganacaea	ME+IR-TR	Th
Salsola imbricata (Forssk.)	Chenopodiaceae	SA-SI+S-Z.	Ch
Salvadora persica L.	Salvadoraceae	S-Z+SA-SI.	Ph
Senecio flavus (Decene) Sch. Bip.	Compositae	SA-SI+S-Z.	Th
Sesbania sesban (L) Merr.	Leguminosae	S-Z.	Ph
Solenostemma argel (Del.) Hayne	Asclepiadaceae	SA-SI+S-Z.	Ph
Sonchus oleraceus L.	Compositae	COSM.	Th
Stipagrostis plumosa (L.) Munro ex T. Andersson.	Gramineae	SA-SI+S-Z+IR-TR+ME.	H
Tamarix aphylla (L.) H. Karst.	Tamaricaceae	SA-SI+S-Z+IR-TR+ME.	Ph
Tamarix nilotica (Ehrenb.) Bunge.	Tamaricaceae	SA-SI+S-Z+IR-TR+ME.	Ph
Tephrosia purpura (L.) Pers.	Leguminosae	S-Z+SA-SI.	Ch
Trianthema triquetra (Forssk).	Aizoaceae	PAL.	Th
Tribulus ochroleucus (Maire)	Zygophyllaceae	PAN.	Th
Tribulus pentandrus Forssk.	Zygophyllaceae	S-Z+SA-SI.	Th
Trichodesma africanum (L.) R. Br.	Boraginaceae	S-Z+SA-SI.	Ch
Typha domingensis (Pers.) poir. ex. Steud.	Typhaceae	PAN.	He
Zea mays L.	Gramineae	Cultivated.	Th
Zilla spinosa L.	Cruciferae	SA-SI.	Ch
Ziziphus spina-christi (L.) Desf.	Rhamnaceae	S-Z+SA-SI.	Ph
Zygophyllum simplex L.	Zygophyllaceae	S-Z+SA-SI.	Th

Tab. 4. Simple linear correlation coefficient (r) between the soil variables and DCA axes. *: $P < 0.05$, **: $P < 0.01$.

Edaphic variable		DCA axis			pH	EC	HCO_3	Cl	Ca	Mg	Silt	Clay	Sand
		AX1	AX2	AX3	mS^{-1}		mg 100 g^{-1}				%		
AX1		1.00											
AX2		–0.22	1.00										
AX3		0.33	0.16	1.00									
pH		0.65	0.06	0.37	1.00								
EC mS^{-1}		0.81^{**}	–0.10	0.40	0.34	1.00							
HCO_3	mg 100 g^{-1}	–0.32	0.67	–0.02	–0.08	0.00	1.00						
Cl	mg 100 g^{-1}	0.32	0.09	0.67	0.04	0.69	0.24	1.00					
Ca	mg 100 g^{-1}	0.59^{**}	0.24	0.37	0.42	0.88^{**}	0.29	0.67	1.00				
Mg	mg 100 g^{-1}	0.78^{*}	–0.27	0.40	0.19	0.95^{**}	–0.11	0.74^{*}	0.72^{*}	1.00			
Silt	%	0.70	0.23	0.76^{*}	0.59	0.64	0.08	0.49	0.55	0.58	1.00		
Clay	%	0.89^{**}	0.05	0.50	0.50	0.93^{**}	0.03	0.67	0.80^{*}	0.90^{**}	0.77^{*}	1.00	
Sand	%	$–0.94^{*}$	0.03	–0.45	–0.58	$–0.90^{**}$	0.02	–0.53	$–0.73^{*}$	$–0.86^{**}$	$–0.81^{*}$	$–0.98^{**}$	1
O.M	%	0.76^{*}	–0.14	–0.01	0.47	0.38	–0.24	–0.22	0.10	0.37	0.54	0.52	–0.67

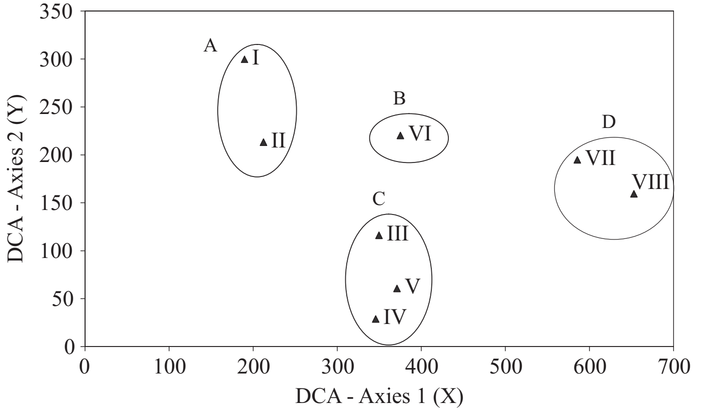

Fig. 5. DCA ordination of the eight vegetation clusters identified in Wadi Allaqi.

cinerea. These species were also recorded by (KASSAS and GIRGIS 1965, SHEDED 1992) as dominant species in some wadis in the Eastern Desert of Egypt including Wadi Allaqi. Three species were recorded for the first time in Wadi Allaqi: *Iphiona scabra*, *Chenopodium album* and *Lotus deserti*. However, SHEDED (1992) recorded *Iphiona scabra* in the Red Sea region (never recorded by other authors, such as ALI et al. 1997& 2000). The appearance of these species may be due to the increasing grazing pressure in Wadi Allaqi that extends to the Sudanese borders, the cultivation of some crops along the shoreline of Lake Nasser, the effects of Lake Nasser itself on the migration of certain species, and the camel trade between Sudan and Egypt (ALI et al. 2000). The life form spectrum reflects a typical desert flora, the majority of species being therophytes and chamaephytes (about 57 %). Life forms of desert plants are also closely related with topography (KASSAS and GIRGIS 1965, ZOHARY 1973 and ORSHAN 1986). According to HASSIB (1951), therophytes are the most common life form in the Egyptian flora.

The communities of wadi ecosystems of the basement complex country are demonstrated by KASSAS and GIRGIS (1969) into four types: ephemeral, suffrutescent woody, suffrutescent succulent and scrubland types. In the present study, the ephemeral type is represented by *Morettia philaeana* and *Fagonia indica* in the downstream and midstream parts of Wadi Allaqi. The suffrutescent type is represented by the community of *Aerva javanica* and *Senna alexandrina* in Wadi tributaries particularly at the middle part. The suffrutescent succulent type is represented by *Salsola imbricata* and *Aerva javanica* which clearly appear in the main channel of Wadi Allaqi and some of its tributaries. The scrubland type is represented by the following shrubs and trees (see also SHEDED 1992): 1- *Tamarix nilotica* community,common in the downstream part, 2- *Salvadora persica* community, which appears in small scale in the upstream part (associated with *Solenostemma arghel*, *Leptadenia pyrotechnica, Balanites aegyptiaca, Acacia tortilis* subsp. *raddiana* and *Acacia tortilis* subsp. *Tortilis*), 3- *Balanites aegyptiaca* community, well represented in the upstream and midstream parts (associated with *Salvadora persica*, *Acacia tortilis* subsp. *raddiana*, *Acacia tortilis* subsp. *tortilis* and *Calotropis procera*), 4- *Leptadenia pyrotechnica* community, well represented in the upstream part (mainly associated with *Calotropis procera*, *Solenostemma arghel* and *Maerua crassifolia*), 5- *Acacia ehrenbergiana,* which community could be dominant in the downstream part and in some scattered small-sized places. 6- *Acacia tortilis* subsp. *tortilis* community, well represented in the upstream part (associated with *Acacia tortilis* subsp. *raddiana* and *Balanites aegyptiaca*), 7- *Acacia tortilis* subsp. *raddiana* community well represented in all parts of the Wadi (in the downstream and midstream parts it is associated with *Acacia ehrenbergiana* but in the upstream part with *Acacia tortilis* subsp. *tortilis, Leptadenia pyrotechnica, Balanites aegyptiaca, Solenostemma arghel* and *Salvadora persica*).

Soil analysis in the present study, indicated that some stands appear to be acidic (it is indicative that the pH of some stands in cluster II was 6.7). This is may be due to the inundation of these stands by the water of Lake Nasser, as well as the effects of livestock excreta on the soil characteristics. The soils of Wadi Allaqi are generally not highly saline, salt being brought to the surface by evaporation following surface irrigation (PULFORD et al. 1992). However, the electric conductivity in some stands in Sidinab area (Wadi Umm Hambol is located in the downstream part of Wadi Allaqi) is abnormally high values (up to 2960 mS^{-1}) where tamarisk woodland is common. Tamarix has been identified as a major cause of salt accumulation on the soil surface (ALI 1987, SPRINGUEL and ALI 1990). Tamarix also is known to concentrate a high amount of sodium chloride in specialized glands in its leaves (BOSABALIDIS 1992). In addition, there is a relationship between the amount of tamarix litter and the electric conductivity of soil (ALI 1987, BRIGGS et al. 1993 and ALI et al. 2001).

In the downstream part, soil characteristics support the vegetation clusters. This part was inundated by Lake Nasser water due to the rising of water levels and the soil was characterized by relatively high contents of clay and silt. In contrast, the soil of the clusters in the other parts was not affected by inundation processes, and consequently, the sand fraction was relatively high (see the study of SHEDED 1992). The sand fraction was relatively high in the stands of the upstream part (Eigat core area) compared with the other stands. This may be due to the weathering process of granite components, which distinguished the upstream part of Wadi Allaqi. Organic matter had a wide range of variation in relation to the different vegetation clusters, especially in the downstream part of Wadi Allaqi. Livestock and birds play an important role, due to the deposition of their dung in the soil, dead fish, due to the activity of anglers in Lake Nasser, as well as the little microbial activity in the soil surface (VOLK and LOEPPERT 1982).

The eight vegetation clusters, identified after Twinspan, are categorized along the DCA axes 1 and 2 into 4 distinct groups (HILL 1979 a, b). The stands belonging to group A (clusters I and II) are mainly located in the upstream part (Eigat core area) and their soil differs from the that of other areas by a higher concentration of bicarbonates, calcium, magnesium and chlorides, perhaps due to animal grazing, rainfall, floods and their effects on the parent rocks (PULFORD et al. 1992).The stands of group B (cluster VI) are located in the middle part, those of group C (clusters III, IV and V) are located in the downstream and middle parts, while those of group D (clusters VII and VIII) are located in the downstream part (some stands are sometimes inundated by the water of Lake Nasser, and their soils are sandy loam)(SHEDED 1992).

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