Journal of Coastal Research	10	4	978–986	Fort Lauderdale, Florida	Fall 1994

Vegetation Changes in North Sinai Within Three Decades

H.F. EL-Kady and M.N. EL-Shourbagy

Botany Department
Faculty of Science
University of Tanta
Tanta, Egypt

ABSTRACT

EL-DADY, H.F. and EL-SHOURBAGY, M.N., 1994. Vegetation changes in northern Sinai within three decades. *Journal of Coastal Research*, 10(4), 978–986. Fort Lauderdale (Florida), ISSN 0749-0208.

Phytosociological relations of plant groups in Wadi EL-Arish area, north Sinai, have been compared within a period extending from 1958 to 1989. Fifty-six stands were selected in 1958 and eighteen stands in 1989 were found satisfactory to represent variation in vegetation. Application of the TWINSPAN classification and DCA ordination techniques led to the recognition of six groups of stands in 1958 which were reduced to four in 1989. Each group of the 1989 stands denoted resemblance with either one or two groups from those of 1958, but with differences in floristic composition.

ADDITIONAL INDEX WORDS: *Environmental changes, vegetation changes, north Sinai, Wadi EL-Arish, classification, ordination.*

INTRODUCTION

The regeneration success, growth and mortality rates of different species in a plant community may be altered with time due to environmental changes. Consequences of vegetation changes in desert ecosystems have not been studied much though they are of major importance. However, the central issue of the present study is to compare phytosociological relations of plant groups in Wadi EL-Arish area, north Sinai, and their responses to climate and soil within the period extending from 1958 to 1989. This study will encourage further research on a regional basis to understand the biophysical association between vegetation and environment thus allowing simulation of evapotranspiration and the response of vegetation to climate forcing.

STUDY AREA

Wadi EL-Arish basin is considered to be one of the most important geographical features of the Sinai Peninsula and extends for 250 km from the central highlands to its outlet into the Mediterranean. Its drainage system constitutes two main tributaries which are connected to many subsidiary ones and can be compared with the classical drainage lines of other arid and semi-arid regions. The study area was located in the northern portion of Wadi EL-Arish basin, was approximately 70 km in length, 5 km in average width and occupied an area of about 350 km^2 (84,000 Feddans). This area is bounded by EL-Halal anticlinal ridge (Lat. 30° 45′ N) to the south and the Mediterranean coast (Lat. 31° 10′ N) to the north (Figure 1).

GEOMORPHOLOGICAL FEATURES

SHATA (1959) divided the northern sector of Wadi EL-Arish basin into three main divisions: EL-Halal upland area, the foot-hill slopes, and the foreshore plain. The foreshore plain of Wadi EL-Arish is represented by the high plain, the uppermost terraces, and the present channel of the Wadi with its flood plain. EL-Halal upland area rises more than 200 m above the plain and is crossed in a northwest-southeast direction by the master stream of Wadi EL-Arish which is bounded by Cenomanian limestone walls rising to more than 150 m above the present channel.

The foot-hill slopes represent a transitional zone between EL-Halal upland area and the foreshore plain. This zone has a height ranging from 200 to 125 m and a width of about 10 km. Its surface is partly covered with gravel, drift sand, and alluvium and is traversed by the main channel of

93037 received 27 March 1993; accepted in revision 27 August 1993.

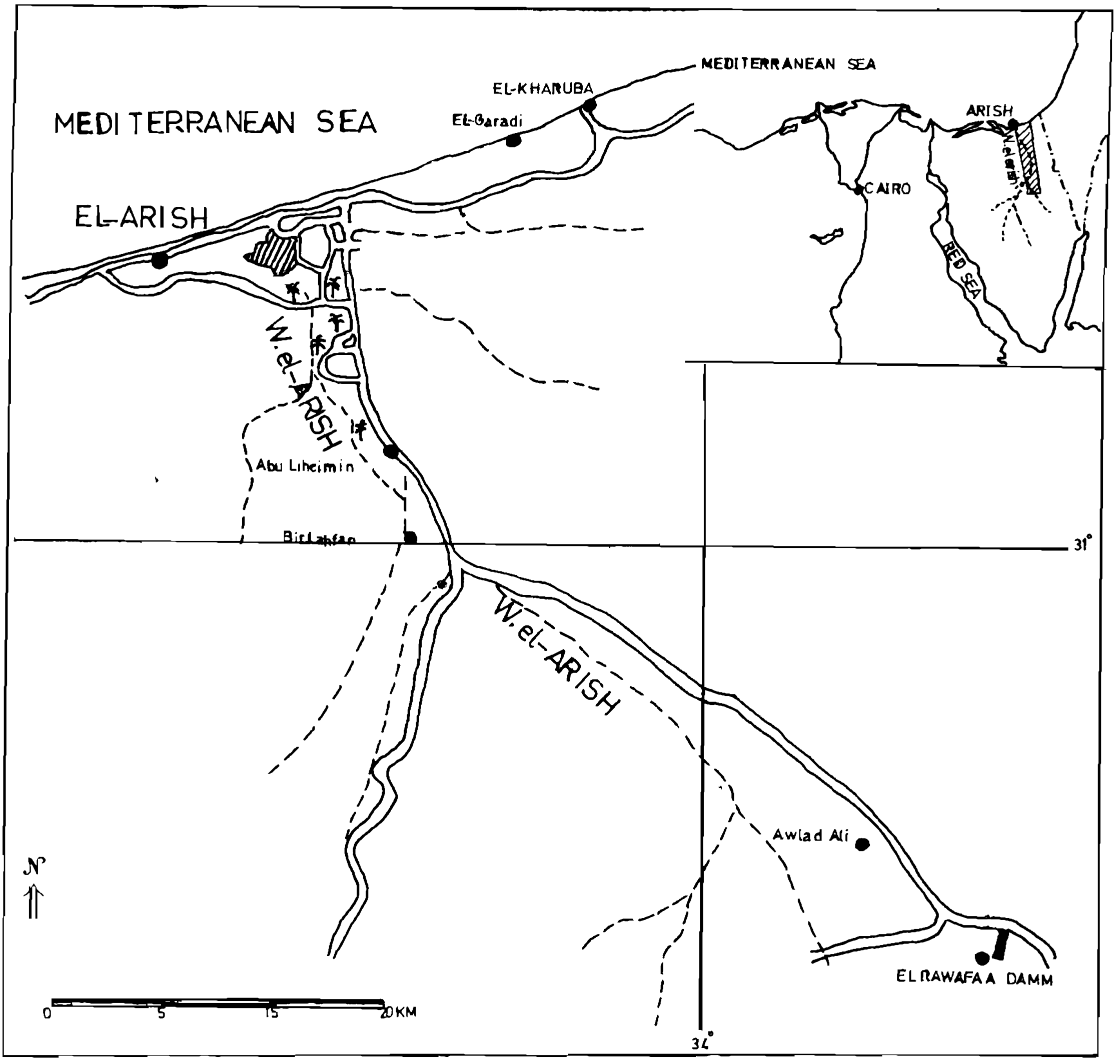


Figure 1. Map showing the study area, represented by the northern portion of Wadi EL-Arish basin and its location on Sinai Peninsula (shaded area).

Wadi EL-Arish. It has different salient features regarding directions, gradients, lateral tributaries, and strata. In the foot-hill region, the general slope gradients are approximately 2.5 m/km except in the northeastern part of EL-Rawafaa (3 km) where it increases to about 5 m/km.

The foreshore plain is dominated by the master stream of Wadi EL-Arish and extends from its exit at EL-Rawafaa gorge in the north to the Mediterranean (over a distance of 50 km). It has a slope of about 2 m/km. The foreshore plain is distinguished into: the high plain; the upper, the middle, and the lower terraces; the flood plain; and the present channel. The high plain is dominated by alluvial formations covered by immense drift sand accumulations. They are locally developed into low lying dunes, which are dissected by a number of shallow drainage lines from the eastern side.

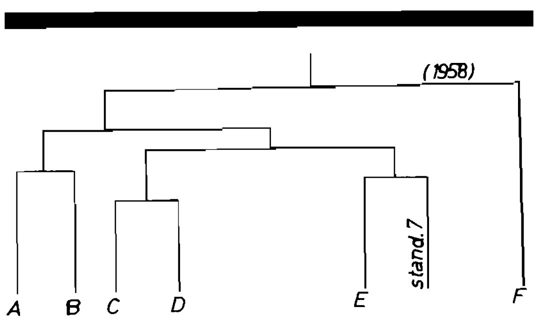
The present channel of Wadi EL-Arish is

Table 1. *Air temperature, relative humidity and rainfall of EL-Arish area from records of the Directorate of Meteorology, Cairo.*

	Averages of 1936–1960					Averages of 1986–1991				
	Temperature (°C)			RH	P	Temperature (°C)			RH	P
Month	Mx	Mn	Dm	(%)	(mm)	Mx	Mn	Dm	(%)	(mm)
Jan.	19.3	8.3	13.8	68	14.5	18.6	8.0	13.3	70	28.8
Feb.	20.1	9.0	14.6	67	16.0	19.8	8.2	14.0	70	13.7
Mar.	21.2	10.7	16.0	65	12.9	20.9	9.6	15.3	71	15.4
Apr.	23.6	13.2	18.4	67	4.3	25.7	12.5	19.1	67	12.1
May	27.0	16.1	21.6	66	3.7	27.3	14.7	21.0	66	1.0
June	28.8	18.7	23.8	69	0.0	30.3	18.0	24.2	64	0.0
July	30.6	21.1	25.8	71	0.0	32.0	20.8	26.4	69	0.0
Aug.	31.0	21.8	26.4	70	0.3	32.0	21.0	26.5	72	0.0
Sep.	29.8	20.3	25.0	68	0.7	30.8	19.8	25.3	73	0.0
Oct.	28.6	17.9	23.2	67	5.3	27.9	16.3	22.1	72	4.3
Nov.	25.2	14.3	19.8	69	18.3	24.5	11.4	18.0	71	9.1
Dec.	21.4	10.1	15.8	69	20.8	20.7	9.0	14.9	69	13.9
Ann. mean	25.6	15.1	20.4	68	96.8*	25.9	14.1	20.0	69.5	98.3*

Where Mx = mean daily maximum, Mn = mean daily minimum, Dm = absolute mean of day, RH = mean daily relative humidity, P = rainfall, and * = total rainfall.

bounded on both sides by three main terraces—the upper, the middle and the lower—which represent the successive stages in its evolution during Holocene times. The upper portion is dominated by light brown sands (hardened dunes) and underlain by sandstones and yellow calcareous clays which appear on the escarpment at the middle level. The lower portion is characterized by bands of gravel and coarse sand.



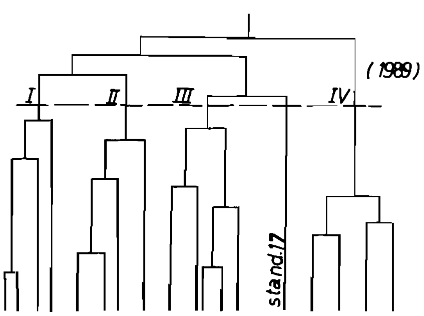


Figure 2. Dendrograms showing the results of classification of stands of 1958 and 1989 according to TWINSPAN method.

The present channel of Wadi EL-Arish and its flood plain have a width varying from a few meters to more than 50 meters and slopes northwards at a rate of 2 m/km. The bed of the present channel is composed of a variety of rock formations which include the Eocene chalk series covered with a mantle of loose gravel and alluvium of variable thickness; the Miocene marls; the Pliocene conglomerates covered with loose gravel and alluvium; and the hard conglomerates of Pliocene age covered with a mantle of recent gravel, silt, and sand. However, the alluvial and diluvial deposits of the Wadi itself are mainly composed of gravel and alluvium mixed with drifted sand.

CLIMATE

The climate of the study area may be classified as transitional between the Monsoon and Mediterranean climate types, owing to the modification by the elevated Sinai Peninsula. Average air temperature, relative humidity and rainfall during 1936–1960 and 1986–1991 are presented in Table 1. In summer (June, July and August), the mean maximum air temperatures ranged between 28.8 and 31.1 °C during the 1936–1960 period and 30.3 and 32 °C during the 1986–1991 period (Table 1). In winter (December, January and February), the mean maximum air temperatures ranged be-

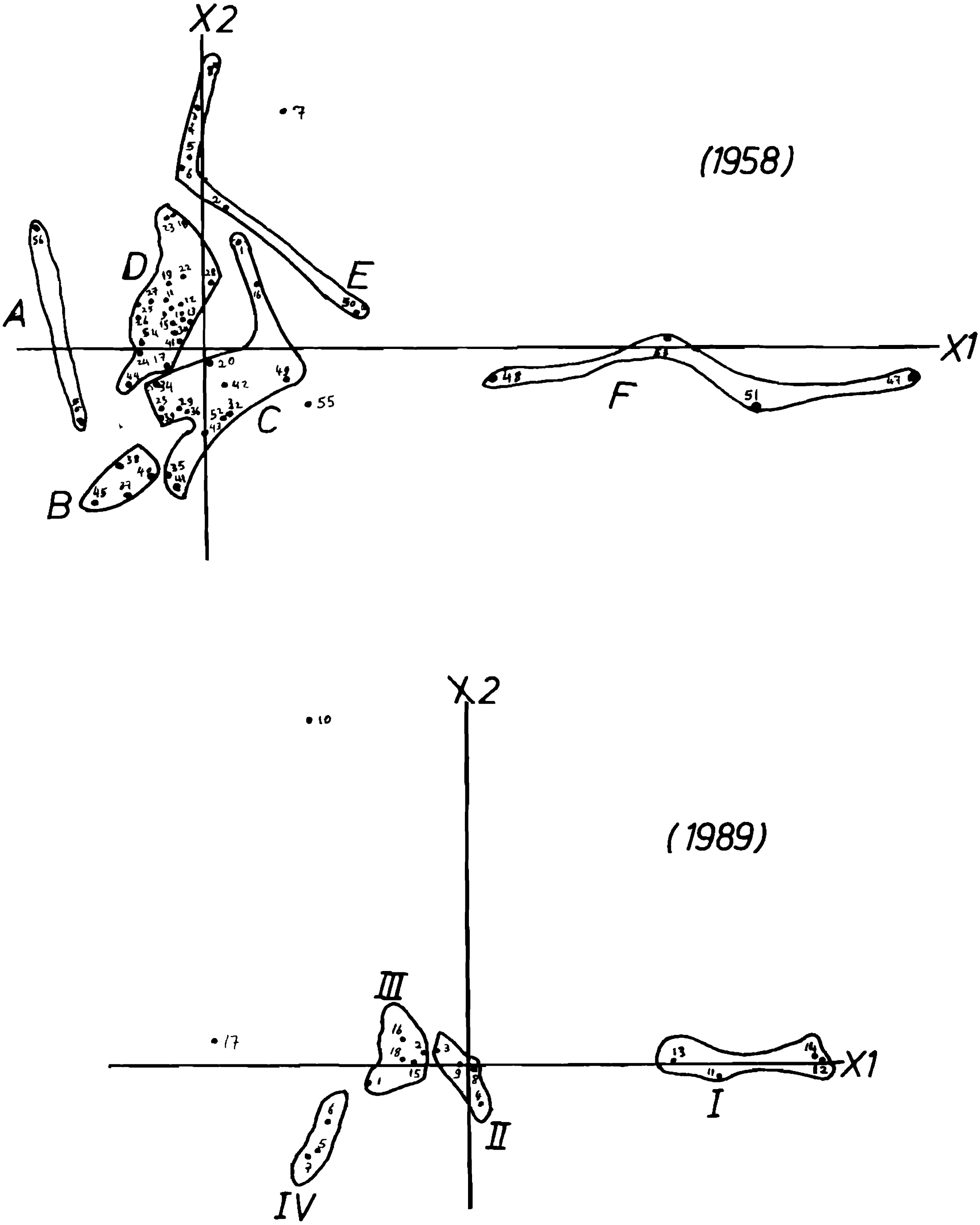


Figure 3. Distribution of stands of 1985 and 1989 on the X-Y ordination plane from the DCA analysis. Classification of stands according to TWINSPAN technique has been superimposed on the ordination plane.

Table 2. *Presence percentage (P) of the species vegetation groups recognized in Wadi AL-Arish in 1958 and 1989.*

	Vegetation Groups											
	1958						Total	1989				Total
Species	A	B	C	D	E	F	P	I	II	III	IV	P
Perennials												
Achillia fragrantissima									25	17	50	22
Alhagi maurorum					13	50	5					
Ammophila arenaria										17		6
Anabasis articulata		50	88	95	100	50	84		75			17
Anabasis oropeadiorum								25	25			11
Artemisia herba alba								50				11
Artemisia monosperma		100	100	77	38	10	75		50	100	25	56
Asphodelus tinuifolius			6	9	25		11	75	75	17		39
Astragalus spinosus		25	19	36			21		50			11
Astriscus graveolens								50				11
Atractylis carduus								75		17		22
Atriplex halimus						25	2	10				6
Capparis aegyptia					13		2					
Centaurea calcitrapa		25		5	13		4	50	100	17		39
Cleome africana			13	5	25		7		25	17		11
Citrullus colocynthis		75	19	5	13		14		25			6
Convolvulus lanatus	50	75	38	68		25	46		75	17	50	33
Cornulaca monacantha		75	44	41			34		75		100	39
Crucianella maritima										50		17
Cynodon dactylon		25	25	5	25		14			33		11
Cyperus sp.										33	25	17
Echinops spinosissimus										17		6
Echiochilon fruticosum			86		13		4		25	17		11
Echium sericeum		25	6				4					
Elymus farctus										17		6
Ephedra alata				5			2					0
Euphorbia retusa		50	25	9	13		18			17		6
Fagonia arabica	50	100	56	91	38		66	25	50	33	75	39
Fagonia mollis								25	50		25	28
Farsetia aegyptiaca			13	23			13		50			11
Gymnocarpos decandrum			25	27			18	50	25			17
Halogeton alopecuroides				5			2					
Hammada scoparia		25	19		88		21	100				22
Haplophyllum tuberculatum				5	13		4			33		11
Helianthemum lippii								50	50			22
Heliotropium arabinsis		75	6		13	25	11			33		11
Hyoscyamus muticus	50	100	25	23	13		29		25			6
Juncus acutus						25	2					
Lotus criticus									50	50		28
Lycium europaeum			13	5		25	11	50	25	33		28
Marrobium allysson										17		6
Marrubium vulgare			13				5					
Matricaria sp.		50					4					
Minuartia procumbens								25				6
Moltikiopsis ciliata									50	50	50	39
Moricandia nitens								25				6
Nitraria retusa			6	9	25	50	13					
Noaea mucronata			69	77	38	25	57	25	25	17		17
Odontospermum graveolens	50		13	23	38		20					
Ononis serrata										17		6
Ononis vaginalis										33		11
Panicum turgidum	50	100	75	36		50	48		25	33		17
Peganum harmala		25	19	5		25	16					
Pergularia tomentosa		25	6				5	25				6
Phragmites communis						25	2					
Pituranthos tortuosus	50	25	38	68	13	25	45		25			6

Table 2. *Continued.*

	Vegetation Groups											
	1958						Total	1989				Total
Species	A	B	C	D	E	F	P	I	II	III	IV	P
Plantago albicans		8					2	25	25	33		22
Reaumuria hirtella				5			2	25				6
Retama raetam	50	25	19	45		50	30		25		50	17
Salvia lanigra								75	25			22
Siline succulenta										33		11
Stipagrostis plumosa	50	100	19	18			23	75	50	33	25	44
Tamarix sp.			38	14		100	27			50		17
Thymelaea hirsuta		75	75	59	38	25	57	25	100	83	25	61
Zilla spinosa			6				2					
Zygophyllum album	50			9			5	25	50		25	22
Zygophyllum coccineum											25	6
Ephemerals												
Astragalus stella								25				6
Bassia muricata		25		5			4		50	33	25	28
Bupleurum lancifolium								50				11
Calendula micrantha								25				6
Outandia dicotoma									50	50	25	33
Erodium hirtum								50	25	50		33
Filago desertorum								25	25			11
Francoeuria crispa			19	5	13		11					
Gastroctyle hispida									25			6
Herniaria hemistemon								75	25	17		28
Hordeum leporinum								50				11
Ifloga spicata						25	2	100	75	67		61
Launea resedifolia								75	75	67		56
Malva parviflora										17		6
Matthiola livida										33	75	28
Medicago intertaxa								50		17		17
Neurada procumbens					13		2		75	50	25	39
Olegomeris linifolia									50		25	17
Pancratium maritimum									50	17	75	33
Plantago crypsoides								75	25			22
Pseudorlaya pumila										50		17
Scabiosa sp.										17		6
Schismus barbatus								100	75	50		56
Senecio desfontainei										17		6
Siline villosa									75	33	25	33
Spergularia sp.									25	33		22
Stipa capensis								25				6
Trigonella stellata								50	100	33	25	50

A: *Z. album–S. plumosa*, B: *P. turgidum*, C: *A. monosperma*, D: *A. articulata–A. monosperma*, E: *A. articulata–H. scoparia*, F: *Tamarix* sp. I: *H. scoparia–A. herba-alba*, II: *T. hirsuta–A. articulata*, III: *A. monosperma*, IV: *C. monantha–F. arabica*

tween 19.3 and 21.4 °C during 1936–1960 period and 18.6–20.7 °C during the 1986–1991 period. It can be noted that during the warmer period, extending from April until September, the mean maximum temperature was consistently higher in the late 1980's than the late 1950's. This is associated with higher absolute means from April until September regardless of the lower mean minimum temperatures. Thus, the late 1980's were characterized by warmer summers and cooler winters than the 1936–1960 period.

In contrast, relative humidity showed higher (69.5) annual means in the late 1980's than in 1936–1960 (68.0) during most of the year except for the warmer season (April until July). Records of the total annual rainfall showed an average of 96.8 mm in 1936–1960 and 98.3 mm in the late 1980's.

METHODS AND TECHNIQUES

Vegetation analysis of the Wadi EL-Arish area was carried out in the summer of 1958 (late 1950's),

Table 3. *Soil variables in stands representing different vegetation groups in 1958 and 1989.*

	Vegetation Groupings 1958					
Soil Variables	A	B	C	D	E	F
pH	7.8			8.1	7.9	8.1
EC (mmhos/cm)	0.14		0.13	0.08	0.12	0.41
Cl (ppm)	320		210	283	160	1,130
SO_4^{2-} (ppm)	1,000			27	290	3,065
$CaCO_3$ (%)	80		76	71.3	54	184

	1989				
	I	II	III	IV	
pH	7.0	7.5	7.3	7.6	*
EC (mmhos/cm)	1.53	0.19	0.19	0.15	
Organic matter (%)	1.4	0.77	0.42	0.20	*
K^+ (ppm)	45	15	25	20	
Na^+ (ppm)	810	200	160	170	
Ca^{2+} (ppm)	1,125	375	340	350	*
Particle fractionation					
Sand %	77.4	88.0	91.7	85.0	*
Silt %	10.0	3.9	2.8	5.5	
Clay %	12.6	8.1	5.5	9.5	

*$P < 0.05$ between groups

and the same area was examined after three decades (in 1989). The analysis was based on the combined estimation of the cover-abundance scale together with the sociability values (BRAUN-BLANQUET, 1964). Presence percentage was obtained from a number of stands in which the taxon occurs. Plant specimens were collected and identified according to TAECKHOLM (1974) and then preserved. Similarity between different stands was assessed using a Two-Way Indicator Species Analysis (TWINSPAN) according to HILL (1979a). Also, the Detrended Correspondence Analysis (DCA) was used as an ordination method that overcame defects of ordinary reciprocal averaging. A detailed description of the procedures and a FORTRAN program for carrying them out has been described in HILL (1979b).

Soil samples were collected in each stand from two trenches dug to a depth of 50 cm. Samples of uniform color and texture were mixed, air dried, and passed through a 2 mm sieve. The hydrometer method was used for the particle fractionation and percentages of sand, silt and clay were calculated. Organic matter was determined by the loss on ignition method by heating samples at 500 °C for 2 hours. $CaCO_3$ was estimated by means of a Collin's calcimeter. In this method, the soil was treated with dilute HCl and the weight of $CaCO_3$ equivalent to CO_2 produced was determined. Soil water extracts (1:5) were prepared and soil reaction (pH), electrical conductivity (EC), Na^+, K^+, Ca^{2+}, Cl and SO_4^{2} were measured. The pH was measured by means of a pH meter and the electrical conductivity (EC) by a conductivity bridge. Chloride concentration was estimated using the $AgNO_3$ titration method and sulfates by "the gravimetric technique with ignition of residue". For the other elements, Na^+, K^+ and Ca^{2+}, a flame photometer (Model 410 CSI, U.K.) was used. All the above procedures are according to the U.S. SALINITY LABORATORY STAFF (1954) and ALLEN *et al.* (1974). Statistical analysis of soil data was performed by using the analysis of variance technique as outlined by STEEL and TORRIE (1980).

RESULTS AND DISCUSSION

In the present study, 49 perennial species were encountered in the summer of 1958 as compared to 53 perennials in the spring of 1989. None of these can be considered as a leading dominant for the whole study area. Fifty-six stands were selected in 1958 and eighteen in 1989, which were found to be satisfactory to represent variation in the vegetation where the abiotic habitat factors showed discontinuity or marked transition. Application of the TWINSPAN program (HILL, 1979) had resulted not only in classifying stands, but also constructed an ordered two-way table. Each group of stands was characterized by a group of differential species (Table 2).

The dendrograms shown in Figure 2 are derived from the TWINSPAN classification. There were six main clusters in 1958 which have been reduced to four in 1989. In 1959, cluster A linked two stands, cluster B four stands, cluster C 16 stands, cluster D 22 stands, cluster E 8 stands, and cluster F four stands. In 1989, each of the clusters I, II and IV linked four stands and III six stands. Ordination of stands by the application of the Detrended Correspondence Analysis (DCA) had resulted in six distinct groupings for 1958 and four for 1989 (Figure 3), which coincided closely with the clustering on the derived dendrograms. Results indicated that stands linked in groups E and F of 1958, characterized by *Anabasis articulata-Hammada scoparia* and *Tamarix* sp., respectively, and those in group I of 1989, characterized by *Hammada scoparia-Artemisia herba alba*, were isolated from the other vegetational categories. On the other hand, groups E and F of 1958 denoted some resemblance with group I of 1989. Replacement of dominants in groups E and F with those in group I can be attributed to environmental changes: mainly air temperature, moisture and soil salinity. Changes in climate will likely alter differentially the regeneration, success, growth and mortality rates of plants. The resulting changes in competitiveness of species or species groups will affect community composition. Air temperature directly influences basic processes such as photosynthesis and respiration. Both respond differently to temperature increases, at least during the dry season (Table 1), which can be used to support the argument that warming may result in reduction of carbon uptake (WOODWELL, 1987).

Furthermore, stands linked in groups A and B of 1958, characterized by *Z. album-S. plumosa* and *P. turgidum-S. plumosa*, respectively, gave place to stands linked in group IV of 1989, characterized by *C. monocantha-F. arabica* (comparable pH and EC values, Table 3). Such changes in dominants may be explained in terms of a shift in competitive or tolerance strategy as a result of either nutrient leaching, mainly Na^+ (for *Z. album*) or overgrazing (*P. turgidum*). Investigations have confirmed that there is a strong correlation between low potential growth rate and tolerance of mineral nutrient deficiencies (HACKETT, 1965; GRIME and HUNT, 1975). On the other hand, KINGSBURY *et al.* (1976) examined the response of the annual halophyte *Lasthenia glabrata* to various periods of osmotic stress and observed that prolonged exposure to salt stress conditions induced a high ratio of flowers to biomass, a relatively low vegetative yield, and a life-cycle which was accelerated and condensed. It appears possible that shifts in competition coincident with changes in environment during the three decades may be attributed to non-competitive effects such as overgrazing rather than to alterations in the relative abilities of *P. turgidum* to compete for resources (NEWMAN, 1973). The latter effect, however, may be clearly pronounced in the replacement of *A. monosperma* in stands linked in group D of 1958 with *T. hirsuta* in stands linked in group II of 1989. Again, it is apparent that stands linked in group C of 1958 corresponded to those linked in group III of 1989. Both are characterized by *A. monosperma*, which explains the relatively higher capacity to tolerate environmental changes.

LITERATURE CITED

ALLEN, S.E.; GRISHAW, H.M.; PARKINSON, J.A., and QUARMBY, C., 1974. *Chemical Analysis of Ecological Materials*. New York: Blackwell, 565p.

BRAUN-BLANQUET, J., 1964. *Pflanzensoziologie*. 3 Auflage, 865p.

GRIME, J.P. and HUNT, R., 1975. Relative growth rate: Its range and adaptive significance in a local flora. *Journal of Ecology*, 63, 393–422.

HACKETT, C., 1965. Ecological aspects of the nutrition of *Deschampsia flexuosa* (L.) Trin II: The effects of Al, Ca, Fe, K, Mn, N, P, and pH on the growth of seedlings and established plants. *Journal of Ecology*, 53, 315–333.

HILL, M.O., 1979a. *DECORANA—A FORTRAN Program for Detrended Correspondence Analysis and Reciprocal Averaging*. Ithaca, New York: Cornell University, 52p.

HILL, M.O., 1979b. *TWINSPAN—A FORTRAN Program for Arranging Multivariate Data in an Ordered Two-way Table by Classification of Individuals and Attributes*. Ithaca, New York: Cornell University, 90p.

KINGSBURY, R.W.; RADLOW, A.; MUDIE, P.J.; RUTHERFORD, J., and RADLOW, R., 1976. Salt stress responses in *Lasthenia glabrata*, a winter annual composite endemic to saline soils. *Canadian Journal of Botany*, 54, 1377-1385.

NEWMAN, E.I., 1973. Competition and diversity in herbaceous vegetation. *Nature*, 244–310.

SHATA, A., 1959. Ground water and geomorphology of the northern sector of Wadi EL-Arish basin. *Bulletin Society de Geographie d'Egypte* 32, 217–245.

STEEL, R.G.D. and TORRIE, J.H., 1980. *Principles and Procedures of Statistics*. New York/London: McGraw-Hill.

TAECKHOLM, V., 1974. *Student's Flora of Egypt.* Edition 2, published by Cairo University.
U.S. SALINITY LABORATORY STAFF, 1954. *Diagnosis and Improvement of Saline and Alkaline Soils.* U.S. Department of Agriculture Handbook 60, U.S. Government Printing Office, Washington, D.C.
WOODWELL, G.M., 1987. Forests and climate: Surprises in store. *Oceanus,* 29, 71–75.