Habitat heterogeneity and soil-vegetation relations in south of the Nile Delta, Egypt

Hétérogénéité des habitats et relations entre le sol et la végétation dans le sud du delta du Nil, Égypte

Monier M. ABD EL-GHANI*[1],
Maged M. ABOU-EL-ENAIN[2],
A. I. ABOEL-ATTA[2]
& Ethar A. HUSSEIN[2]

1. The Herbarium, Faculty of Science, Cairo University, P.C. 12613, Giza, Egypt

2. Biological and Geological Sciences Department, Faculty of Education, Ain Shams University, Roxy, Heliopolis, P.C.11757, Cairo, Egypt

* Author for correspondence (e-mail: elghani@yahoo.com)

Abstract

Floristic composition and soil characters in representative habitats of the southern Nile Delta region in Qalyubia were analyzed in terms of habitat variations and species diversity. A total of 90 sites were surveyed and nineteen environmental factors were recognized in four main habitats: canal banks, cultivated lands, waste lands and sandy plains. Basic statistical treatments were established by using SPSS v. 10.0. The produced data were subjected to cluster analysis by using MVSP v. 3.1; indirect and direct ordination methods i.e. *Detrended and Canonical Correspondence analyses, respectively by using CANOCO v. 4.5. A total of 164 species representing c. 7.7% of the Egyptian plant species were recorded and their life-form spectrum was identified. The majority of species were belonging to the families: Gramineae, Compositae, Leguminosae and Cruciferae. The floristic similarity between the recognized habitats showed a significant positive correlation between the canal banks and cultivated lands.* Cynanchum acutum *subsp.* acutum, Cynodon dactylon, Phragmites australis *and* Pluchea dioscoridis *were of high ecological amplitude. Three main vegetation groups* (i.e. *weeds, halo/ helophytes and xerophytes) were recorded, and their controlling ecological factors were identified. Ordination analysis reveled that, the three groups were well segregated along the DCA axis 1, and were highly related to calcium carbonates, fertility and species diversity gradients in addition to the gradient of human interference. Canonical Correspondence Analysis (CCA) produced a similar pattern to that of the floristic Detrended Correspondence Analysis (DCA) and revealed that, the weed plants (*i.e. *vegetation group A) were highly associated with organic matter, phosphorus, potassium, saturation percentage, potassium cations and pH; the Halo/Helophytic plants (group B) with bicarbonates, sulphates, calcium, magnesium and sodium; the xerophetic plants (group* C) with $CaCO_3$ and pH.

Keywords: Weeds, Multivariate analysis, Plant diversity, CCA, agro-ecosystem.

Introduction

Plant formations are the largest and most complex units of vegetation and represent the level at which most world maps are compiled. Their distribution is generally determined by climate and influenced by biotic factors and soil characteristics (Parker 1991). The differences in soil conditions produced by interaction of climate, topography and vegetation over the time have a profound effect on the plant communities and other biological systems that they support. In Egypt, the Nile system includes a number of soil types among different habitats, which are formed and/or greatly influenced by the water of the River Nile. Some of these habitats are natural *e.g.* coastal dunes, salt marshes and brackish shallow lakes. The others are man-made *e.g.* canal banks of irrigation water and drains, roads and

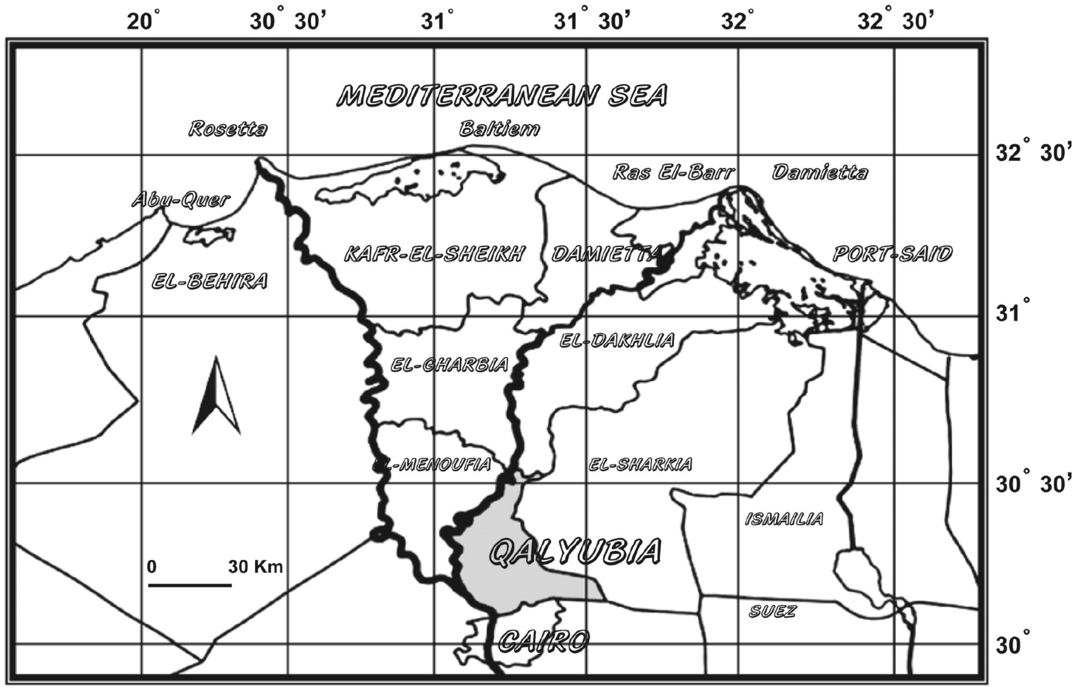

Figure 1 – Map of the Nile Delta region showing the study area.

railway lines, waste ground and the abandoned and cultivated fields (Shaltout & Sharaf El-Din 1988; Zahran & Willis 1992).

Correlation of soil features and vegetation zones in natural or man made habitats of the Nile Delta region has been investigated by many authors *e.g.* Shaltout & Sharaf El-Din (1988), Shaltout *et al.* (1992; 1994), Shaltout & El-Sheikh (1993), Hassan (2002) and Abd Al-Azeem (2003). The aquatic ecosystems vegetation in such region particularly that of irrigation and drain canal banks were also investigated by Shaltout *et al.* (1994), Serag & Khedr (1996) and Mashaly *et al.* (2001; 2003; 2009). However, in Qalyubia the subject matter of the present study, sporadic works that almost restricted to one or two habitats have been made *e.g.* Shams *et al.* (1986) on the aquatic habitat; Shams *et al.* (1987a) on the uncultivated land; Shams *et al.* (1987b) on the natural vegetation of Khanka-Abu Zaabal areas; El-Sheikh *et al.* (2004) and Galal & Khalafallah (2007) on gardens and flowerbeds in each of El-Qanatir Public Park and Abu-Za'abal artificial wetland, respectively. On the other hand, only two studies (Hassan 2001; Shaltout *et al.* 2005) had included a number of habitats in south Nile Delta but none of them was intended for Qalyubia Governorate in the broad sense. The present work aims at: analyzing the floristic composition and soil characteristics of the main habitats of Qalyubia Governorate and assessing the soil-vegetation relationships that affect plant species distribution in the area.

The study area

The Nile Delta is a classic delta with a triangular shape situated in North Egypt where the Nile River spreads out and drains into the Mediterranean Sea. Its area is approximately 22,000 km^2 and comprises about 63% of the Egyptian agricultural area (Abu Al-Izz 1977). The area chosen for the present study *i.e.* Qalyubia is located as a pear-shape at southern of the Nile-Delta, east of Damietta branch between 31^o 5', 31^o 25'N and 30^o 07' and 30^o 35'E (Figure 1). It is bordered by each of Dakahliya and Menoufiya from the north, Sharkiah from the east, Menoufiya from the west and by each of Giza and Cairo from the south (Abd-El-Aal 1983). The total cultivated area of Qalyubia is about 213456 Acres (Abd-El-Wahab 2004).

Climatically the study area can be classified as arid where the rainfall takes place only during the period from November to February. The annual mean temperature varies between 14.1 ^oC and 19.4 ^oC during winter and 24.5 ^oC to 29.4 ^oC during summer. The mean relative humidity ranges from 45.7% in May, to 60% in December. Evaporation is greater during summer than in winter months; it ranged between 5.2 mm/day in December and 9.1 mm/day in August. The maximum amount of total annual rainfall ranged between 16.3 mm in February and 28.45 mm in March. The average long-term of climatic data over 10 years (from 1999-2009) for this region is obtained from Egyptian Meteorological Department, Cairo. The area slopes gradually from south to north-east where the elevation reaches 17 meters above sea level in the south and less gradually in north-east up to 10 meters. Generally, the relief is fairly uniform apart from the eastern edge of the Governorate where it exceeds 20 meters above sea level.

Three geomorphologic units are found in the study area *i.e.* young alluvial plain, old alluvial plain and structural plain; which are sometimes covered with sand (SMFL 1999). The young alluvial plains occupy most of the Governorate and are characterized by the presence of agricultural land and irrigation network. Silt and deposits of the Holocene era cover these plains whereas in some places Pleistocene deposits are present which are composed of sandy islands surrounded by agricultural lands. Old alluvial plains are located in the south-eastern part of Governorate and are covered with deposits of pebbles, sand and mud lenses of the Pleistocene era. These sediments appear as sandy islands in a few areas inside the young alluvial plains. The structural plains region located at the south-eastern edge of Governorate are covered with deposits of triple era including sand, pebbles and calcareous sand stone that are belonging to Miocene era and basalt rocks of Oligocene era.

Surface water in the study area includes Damietta branch (east of Governorate), Al-Riah El-Tawfiki irrigation canals (Ismailia, Basosia, Sharkawia canals and others) and a group of drainage canals. Their water level increases in summer and decreases in winter, and the direction of water movement is from south to north (SMFL 1999). The vegetation is strongly affected by soil fertility in relation to precipitations of the organic matters and minerals. These and other dissolved substances were found with large quantities in the water of River Nile, but greatly decreased after the establishment of the High Dam (Shams *et al.* 1986).

Materials and Methods

Field data of the floristic composition was gathered following intensive field work during 2008-2010. A total of 90 plots were selected to represent as much as possible the variation of vegetation. In each plot with a size of 1/2 Acre (ca. 2100 m^2), the species were recorded; their voucher specimens were collected and identified at the herbarium of Cairo University (CAI). Taxonomic nomenclature was according to Täckholm (1974), updated by Boulos (1995; 1999; 2000; 2002; 2005). Life-form categories were identified according to Raunkiaer's system of classification (Raunkiaer 1934).

Four main habitats were considered: (1) Canal banks, consisted of the water course itself (the wetted channel), and the associated land or riparian zone viz. slope and embankment; (2) Cultivated lands, represented by the arable lands occupied by field crops and *Citrus spp.* orchards. Agriculture in the study area follows the general Egyptian pattern *i.e.* summer and winter crops (the seasonal sequence). The main included crops were the Egyptian clover (*Trifolium alexandrinum* L.) and wheat (*Triticum vulgare* L.) as winter crops, maize (*Zea mays* L.) and Rice (*Oryza sativa* L.) as summer crops; (3) Waste lands, represented by the barren or desolate areas of lands, not or no longer used for cultivation. The salt-affected areas (not salt marshes) that found either adjacent to the farmlands or around the irrigation canals and may be saturated with drainage water including a high amount of soluble matter (Zahran 1972; Shaltout & El-Sheikh 1993); (4) Sandy plains, consisted of sandy deposits that had low water retention capacity and low capillary power. Arid zones are characterized by minimal precipitation and frequent droughts (Mabbutt 1977).

For each sampled plot, three soil samples were collected from profiles of 0-40 cm; pooled together to form one composite sample; air-dried and thoroughly mixed. Textures were determined with the international pipette method, providing quantitative data on the percent sand, silt and clay. $CaCO_3$ was determined by Collin's calcimeter. Organic matter was estimated by the Walkley-Black method (Upadhyay & Sharma 2002). Soil-water extract (1: 2.5) *w/v* were prepared for the determination of electric conductivity (EC; mS cm^{-1}) using conductivity meter, pH using pH-meter, whereas estimation of chlorides was carried out by titration methods using 0,005 N silver nitrate (Hazen 1989; Kolthoff & Stenger 1974). Carbonates and bicarbonates were determined by titration against 0.1 N HCl (Allen *et al.* 1974). Sulphate content was calculated by difference between anions and cations. Determination of calcium and magnesium were carried out by titration methods with 0,01 N EDTA (Upadhyay & Sharma 2002). Sodium and potassium were determined using flame photometer technique (Jackson 1962). Available nitrogen in the soil samples was extracted with 1% K_2SO_4, then analyzed using the Devarda's alloy micro-Kjeldahl procedure and the steam distillation system (Page 1982), whereas available phosphorus was determined calorimetrically by ascorbic acid method (Watanabe & Olsen 1965). Available potassium was determined by using flame-photometer according to Soltanpour (1985).

In order to obtain an effective analysis of the vegetation and related environmental factors, both classification and ordination techniques were employed. A floristic data matrix of 90 plots and 164 species was subjected to classification by cluster analysis of the computer program MVSP version 3.1 (Kovach 1999) using squared Euclidean distance dissimilarity matrix with minimum variance (also called Ward's method) as agglomeration criterion (Orlóci 1978). The computer program CANOCO v. 4.5 (Ter Braak 2003) was used for all ordination analyses; whereas the computer program SPSS v. 10.0 (SPSS 1999) was used for all the statistical treatments. Detrended Correspondence Analysis (DCA), an indirect gradient analysis technique, was used to identify the main gradients that influence species distribution. Preliminary analyses were made by applying the default option of DCA (Hill & Gauch 1980) to check the magnitude of change in species composition along the first axis (*i.e.* gradient length in standard deviation (SD) units). In the present study, DCA estimated the compositional gradient in the vegetation data to be larger than 4.0 SD-units for the first axis, thus, Canonical Correspondence Analysis (CCA) is the appropriate ordination method to perform direct gradient analysis (Ter Braak 2003). Ter Braak (1986) suggests using DCA and CCA together to see how much of the variation in species data was accounted for by the environmental data. Nineteen environmental factors were included: coarse sand, fine sand, silt, clay, $CaCO_3$, organic matter, saturation percentage, pH, electric conductivity (EC), chlorides (Cl^-), bicarbonates (HCO_3^-), sulphates (SO_4^{-2}), sodium (Na^+), potassium (K^+), calcium (Ca^{++}), magnesium (Mg^{++}) and macronutrients (N, P, K). All the default settings were used for CCA, and a Monte Carlo permutation test (499 permutations; Ter Braak 1994) was used to test for significance of the eigenvalues of the first canonical axis. Intra-set correlations from the CCA's were used to assess the importance of the environmental variables.

Results

In total, the recorded number of vascular plants in the present study is 164 species that belong to 133 genera and 48 families (Appendix 1). The most species-rich families are Gramineae (33 species), Compositae (15), Leguminosae (12), Cruciferae (10), Chenopodiaceae (8), Convolvulaceae (5), Cyperaceae (5), Euphorbiaceae (5) and comprise about 56.7% of the recorded species.

Analyzing the life form spectra (Figure 2; Appendix 1) in the study area revealed that, therophytes are the predominant life form and constituted 50% of the total flora. The other recorded forms with a descending arrangement are cryptophytes (20.7%), hemicryptophytes (10.4%), phanerophytes (9.1%), chamaephytes (8.5%) and parasites (1.2%). The percentage of life-span in the present study (Figure 3) showed that, annuals – as expected – came on top with a percentage of 55.5%, followed by perennial herbs, shrubs, trees and biennials with percentage of 27.4%, 9.1%, 5.5% & 2.5%, respectively.

The species distribution in the study area (Appendix 1) indicates that, some species have been recorded in all or most of the habitats (*e.g. Pluchea dioscoridis*, *Cynodon dactylon* and *Phragmites australis*). On the other hand, seventy-nine species (48.2% of the total) are distributed as follows: 21 in the canal banks (*e.g. Salix mucronata, Mentha longifolia* subsp. *typhoides*, *Eichhornia crassipes*, *Phyla nodiflora* and *Ceratophyllum demersum*), 23 in the cultivated lands (*e.g. Lolium perenne*, *Fumaria densiflora*, *Lepidium sativum* and *Physalis angulata*), 13 in the waste lands (*e.g. Juncus rigidus*, *J. acutus*, *Cyperus laevigatus*, *Cressa cretica* and *Bacopa monnieri*) and 22 in the sandy plains

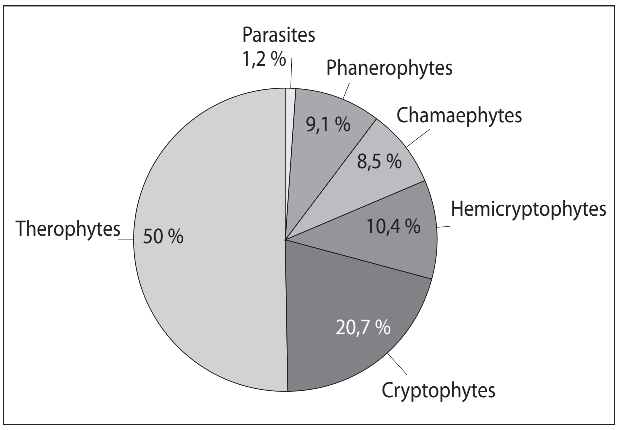

Figure 2 – Life form spectra of the vascular flora of the study area.

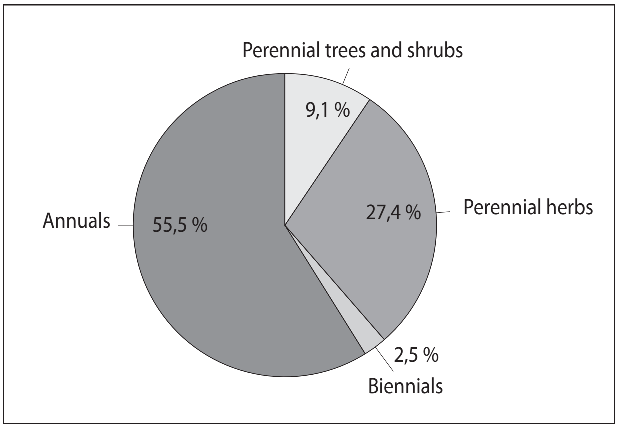

Figure 3 – Longevity (life span) of the vascular flora of the study area.

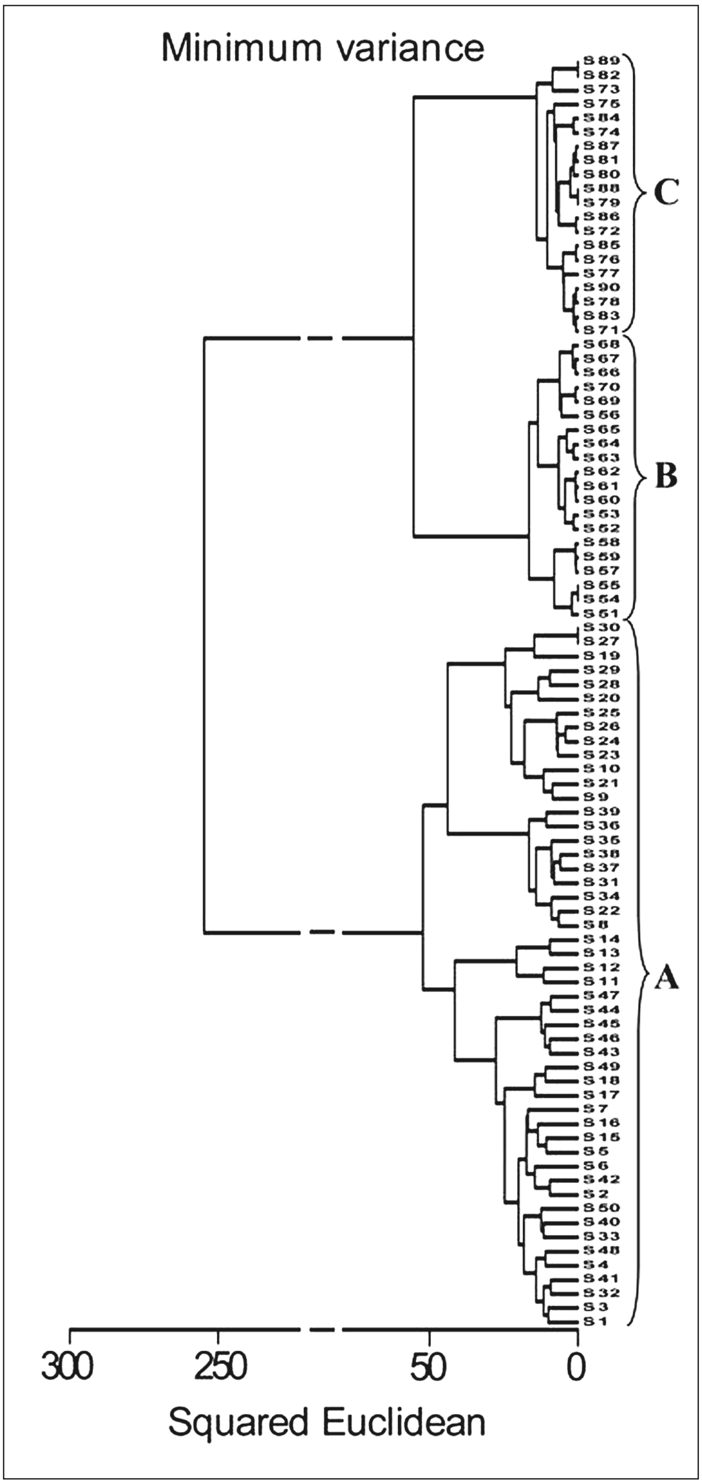

Figure 4 – The produced dendrogram based on cluster analysis of the recognized 90plots in the study area, showing the three separated vegetation groups (A-C).

(*e.g.* *Convolvulus lanatus*, *Fagonia arabica*, *Haloxylon salicornicum*, *Moltkiopsis ciliata* and *Panicum turgidum*).

Classification of the presence-absence data set of 164 species recorded in 90 plots using the cluster analysis yielded three vegetation groups *i.e.* A, B & C (Figure 4; Table 1; Appendix 1). These groups included three common species viz. *Cynanchum acutum* subsp. *acutum*, *Pluchea dioscoridis* and *Phragmites australis*. Group A included 50 plots from canal banks and cultivated lands and comprises 124 species, of which 114 are confined to this group; amongst others; *Echinochloa colona*, *Euphorbia peplus*, *Trifolium resupinatum*, *Cyperus difformis* and *Acacia nilotica*. The leading dominant species (P = 76%) are *Convolvulus arvensis* and *Digitaria sanguinalis*. Thirteen common species are also observed (P = 74-52%); *e.g. Portulaca oleracea*, *Sonchus oleraceus*, *Oxalis corniculata* and *Cynodon dactylon*. Among 22 less commonly species (P = 48-26%) *Euphorbia helioscopia*, *Amaranthus hybridus*, *Melilotus indicus* and *Polypogon monspeliensis* are reported. Sporadically recorded plants included 87 species *e.g. Brassica tournefortii*, *Euphorbia forsskaolii*, *Sida alba*, *Azolla filiculoides* and *Ranunculus marginatus*. It also characterized by occurrence of water-loving species, such as *Echinochloa colona*, *Cyperus rotundus, Paspalidium geminatum* and *Phragmites australis*, and salt-tolerant

Table 1 – Mean values, standard deviations (± SD) and ANOVA F-values of the soil variables of the three vegetation groups obtained by cluster analysis. CS = coarse sand, FS = fine sand, O.M. = organic matter, S.P. = saturation percentage, pH = soil reaction, E.C. = electrical conductivity, Cl^- = chlorides, HCO^-_3 = bicarbonates, SO^{-2}_4 = sulphates, Ca^{+2} = calcium, Mg^{+2} = magnesium, Na^+ = sodium, K^+ = potassium, N = available nitrogen, P = available phosphorus and K = available potassium. * = P ≤ 0.05 and ** = P ≤ 0.01.

Soil variables	Units	Total mean	Vegetation groups			F-ratio	P
			A	B	C		
CS	%	20.33 ± 13.60	10.90 ± 10.49	30.38 ± 6.88	33.84 ± 1.83	69.21	0.000**
FS		27.39 ± 11.11	19.49 ± 8.28	36.02 ± 4.88	38.53 ± 2.15	79.07	0.000**
Silt		28.83 ± 10.21	35.70 ± 8.41	21.12 ± 4.63	19.39 ± 2.0	58.77	0.000**
Clay		23.45 ± 14.54	33.91 ± 10.37	12.50 ± 7.16	8.25 ± 2.13	85.92	0.000**
O.M.		0.27 ± 0.09	0.33 ± 0.07	0.20 ± 0.03	0.18 ± 0.02	71.43	0.000**
$CaCO_3$		4.42 ± 1.04	3.97± 0.80	4.83 ± 1.35	5.13 ± 0.62	13.90	0.000**
S.P.		39.34 ± 15.32	50.50 ± 11.76	25.50 ± 2.08	25.27 ± 0.71	88.83	0.000**
pH	-	7.91 ± 0.38	7.90 ± 0.33	7.83 ± 0.50	8.03 ± 0.33	1.50	0.229
E.C.	mS cm^{-1}	5.46 ± 4.09	4.31 ± 1.70	10.42 ± 6.0	3.39 ± 1.04	33.04	0.000**
HCO_3^-	meq/l	3.67 ± 1.41	3.24 ± 1.15	5.40 ± 1.21	3.04 ± 0.67	33.26	0.000**
Cl^-		48.18 ± 38.88	37.40 ± 15.48	94.57 ± 58.33	28.76 ± 9.64	31.39	0.000**
SO_4^{-2}		2.78 ± 1.17	2.51 ± 1.04	4.15 ± 0.92	2.10 ± 0.31	30.82	0.000**
Ca^{+2}		8.03 ± 4.33	6.58 ± 2.69	13.16 ± 5.66	6.51 ± 1.18	29.79	0.000**
Mg^{+2}		5.11 ± 2.62	4.07 ± 1.53	8.39 ± 3.27	4.44 ± 0.92	36.17	0.000**
Na^+		40.55 ± 34.07	31.40 ± 13.33	81.36 ± 50.88	22.61 ± 8.74	32.20	0.000**
K^+		0.97 ± 0.53	1.12 ± 0.39	1.25 ± 0.59	0.33 ± 0.15	32.95	0.000**
N	ppm	41.51 ± 32.26	64.08 ± 24.86	16.16 ± 15.44	10.42 ± 2.73	71.75	0.000**
P		8.32 ± 5.76	12.44 ± 4.29	3.55 ± 2.48	2.80 ± 1.0	80.14	0.000**
K		133.18 ± 48.55	166.20 ± 41.96	93.48 ± 3.82	90.33 ± 5.03	61.36	0.000**
Species richness (SR)		16.68 ± 9.41	24.44 ± 3.92	7.60 ± 2.54	6.35 ± 3.30	273.22	0.000**
Shannon's index (H')		2.57 ± 0.80	3.18 ± 0.16	1.96 ± 0.40	1.66 ± 0.73	129.75	0.000**

species such as *Cynanchum acutum* subsp. *acutum* and *Beta vulgaris* subsp. *maritima*. Canal banks' vegetation is very rich, and with noticeable stratification. It is inhabited by some trees and shrubs such as *Acacia nilotica*, *Salix mucronata* and *Pluchea dioscoridis*, perennial herbs such as *Verbena officinalis*, *Oxalis corniculata*, *Phragmites australis* and *Phyla nodiflora* and annual herbs such as *Conyza bonariensis*, *Ranunculus sceleratus* and *Eclipta prostrata*. This group is characterized by soil with highest content of silt, clay, organic matter, saturation percentage, nitrogen, phosphorus and potassium and the lowest values of coarse sand, fine sand, $CaCO_3$ and Mg^{+2}.

Group B included 20 plots from waste habitats and comprises 27 species from which 13 are confined to this group *e.g. Juncus acutus*, *Cressa cretica*, *Pulicaria undulata* and *Sonchus maritimus*. The leading dominant species in group B is *Alhagi graecorum* (P = 100%), whereas commonly recorded species (P = 65-60%) are *Juncus rigidus*, *Phragmites australis*, *Desmostachya bipinnata*, *Pluchea dioscoridis* and *Tamarix nilotica.* On the other hand, *Cyperus laevigatus*, *Conyza bonariensis*, *Bassia indica* and *Typha domingensis* showed less common presence (P = 50-30%). Also, seventeen sporadic species are recorded *e.g. Aeluropus lagopoides*, *Bacopa monnieri* and *Silybum marianum*. Their soil exhibited the highest values of E.C., bicarbonates, chlorides, sulphates, Ca^{+2}, Mg^{+2}, Na^+ and K^+ and the lowest value of pH.

Group C comprises 31 species and 20 plots from sandy plains. It is characterized by the dominance of *Haloxylon salicornicum* (P = 95%). Commonly recorded species (P = 55%) are *Convolvulus lanatus*, *Cornulaca monacantha* and *Echiochilon fruticosum*. Less common recorded species (P = 45-30%) are *Heliotropium digynum*, *Tamarix nilotica*, *Cynanchum acutum* subsp. *acutum* and *Moltkiopsis ciliata*. Twenty-three species are occasionally recorded *e.g. Bassia muricata*, *Calligonum polygonoides*, *Centaurea calcitrapa* and *Tribulus bimucronatus* var. *bispinulosus*. The group is characterized by the soil of highest values of coarse sand, fine sand, $CaCO_3$ and pH, and the lowest values of silt, clay, organic matter, saturation percentage, E.C., bicarbonates, chlorides, sulphates, Ca^{+2}, Na^+ and K^+, nitrogen, phosphorus and potassium.

Soil characteristics of each of the three vegetation groups are given in Table 1. The correlations between the measured soil variables are given in Table 2. The ordination graph of the recorded species in the recognized 90 plots along the first two axes of the DCA is illustrated in Figure 5. The first (Eigenvalue = 0.922) and the second (Eigenvalue = 0.394) axes accounted for 9.292% and 3.967%, respectively of the overall floristic variance. CCA draw showing distribution of the recognized 90 plots in relation to their vegetation groups and soil variables is illustrated in Figure (7). The results of ordination for the three CCA axes, inter-set correlation of the soil variables, together with Eigen values and species-environment correlation are given in Table 3.

Discussion

Floristic composition

The vascular plant species recorded (164 in total) in the study area represent about 7.7% of the Egyptian flora (Boulos 1995). The families with the highest richness recorded by this study are compatible with the data of Quezel (1978) who reported that, Gramineae, Compositae, Leguminosae, Cruciferae, Chenopodiaceae, Convolvulaceae, Cyperaceae and Euphorbiaceae are among the most common families in the Mediterranean North African flora. On the other hand, the relatively high number of species recorded in the families Gramineae, Compositae, Leguminosae and Cruciferae are in accordance with the study by Abd El-Ghani & El-Sawaf (2004) who considered these to be the main families as they include the majority of alien plant species in the agro-ecosystem either in Egypt (48.9%) or in adjacent countries. A comparison of the families in terms of the largest species number in the present investigation and in other previous studies; *e.g.* Mashaly (1987) on the North-East Nile Delta, Abd Al-Azeem (2003) on the Nile Delta region and Abd Alla (2007) on the Sharkiya Governorate, corroborate this conclusion.

Dominance of the therophytes among the recorded life form spectrum (Appendix 1) of the studied flora seems to be a response to hot-dry climate, topographic variation and biotic influence that characterize the study area. Heneidy & Bidak (2001) reported that "the short life cycles of field crops (the most prominent land use in the study area) in addi-

Table 2 – Summary of Pearson's correlations between soil variables, species richness (SR) and Shannon's index (H'). For abbreviations, see Table 1. NS = non-significant values. * = P ≤ 0.05 and ** = P ≤ 0.01.

Soil variables	CS	FS	Silt	Clay	O.M.	$CaCO_3$	S.P.	pH	E.C.	HCO_3^-	Cl^-	SO_4^-	Ca^{+2}	Mg^{+2}	Na^+	K^+	N	P	K	SR
FS	.984**	1.000																		
Silt	-.989**	-.988**	1.000																	
Clay	-.993**	-.991**	.977**	1.000																
O.M.	-.789**	-.789**	.774**	.798**	1.000															
$CaCO_3$	.551**	.500**	-.553**	-.509**	-.500**	1.000														
S.P.	-.931**	-.926**	.919**	.933**	.780**	-.498**	1.000													
pH	NS	NS	NS	NS	NS	.247*	NS	1.000												
E.C.	NS	NS	NS	NS	NS	.438**	-.225*	.356**	1.000											
HCO_3^-	NS	NS	NS	NS	-.249*	.299**	NS	NS	.793**	1.000										
Cl^-	NS	NS	NS	NS	NS	.443**	-.226*	.363**	.999**	.772**	1.000									
SO_4^-	NS	NS	NS	NS	NS	.221*	NS	NS	.774**	.814**	.754**	1.000								
Ca^{+2}	.227*	.230*	-.256*	-.208*	-.300**	.504**	-.236*	.284**	.935**	.836**	.929**	.799**	1.000							
Mg^{+2}	.309**	.310**	-.331**	-.294**	-.352**	.495**	-.337**	.271**	.940**	.806**	.936**	.758**	.936**	1.000						
Na^+	NS	NS	NS	NS	NS	.424**	-.218*	.367**	.998**	.774**	.999**	.760**	.914**	.924**	1.000					
K^+	-.394**	-.393**	.357**	.418**	.330**	NS	.348**	.229*	.700**	.534**	.699**	.591**	.626**	.559**	.701**	1.000				
N	-.978**	-.962**	.965**	.973**	.803**	-.548**	.950**	NS	NS	NS	NS	NS	-.229*	-.308**	NS	.405**	1.000			
P	-.964**	-.955**	.948**	.966**	.785**	-.493**	.944**	NS	NS	NS	NS	NS	-.226*	-.313**	NS	.394**	.975**	1.000		
K	-.926**	-.935**	.929**	.928**	.755**	-.521**	.940**	NS	NS	NS	-.207*	NS	-.251*	-.329**	NS	.351**	.942**	.933**	1.000	
SR	-.734**	-.747**	.704**	.763**	.768**	-.465**	.774**	NS	-.279**	-.263*	-.278**	NS	-.345**	-.429**	-.263*	.314**	.726**	.750**	.740**	1.000
H'	-.649**	-.659**	.620**	.675**	.664**	-.472**	.702**	NS	-.238*	-.217*	-.238*	NS	-.292**	-.381**	-.223*	.316**	.640**	.655**	.677**	.937**

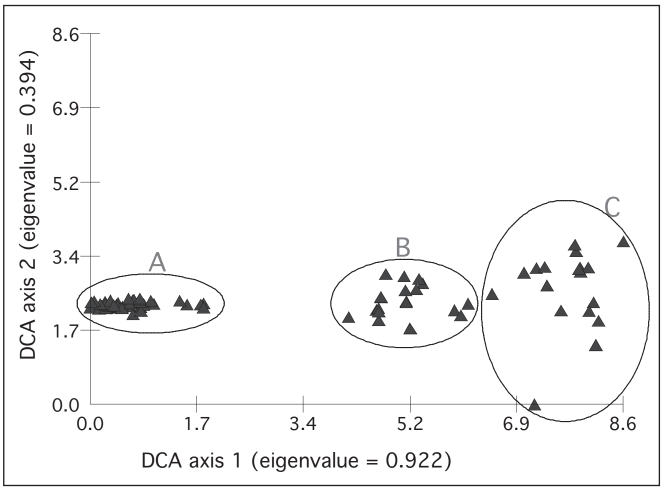

Figure 5 – The Detrended Correspondence Analysis (DCA) ordination draw of the recognized 90 plots in the study area, represent the three cluster groups (A-C) superimposed.

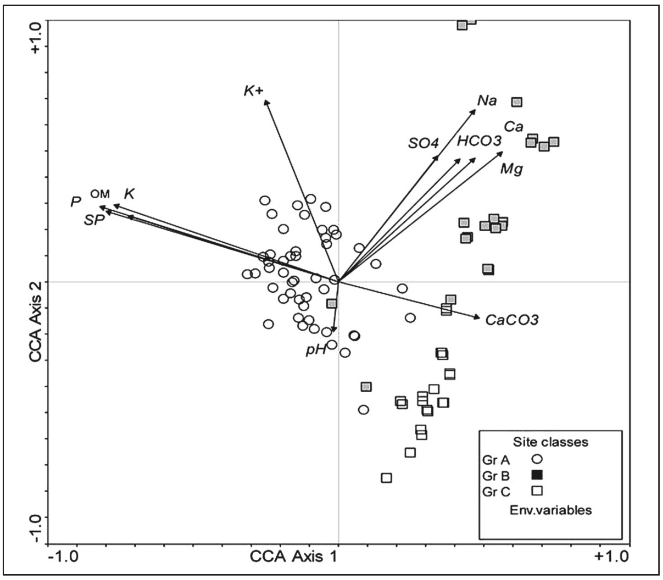

Figure 6 – Canonical Correspondence Analysis (CCA) biplot of axes 1 and 2 showing the distribution of the recognized 90 plots in the study area, with their vegetation groups and soil variables.

Table 3 – The results of ordination for the three CCA axes, inter-set correlation of the soil variables, together with Eigen values and species–environment correlation. For abbreviation and units see Table 1. Figures in bold indicate gradient of axis.

Ordination / Parameter	DCA axis 1	DCA axis 2	DCA axis 3	CCA axis 1	CCA axis 2	CCA axis 3
Eigen values	0.922	0.394	0.288	0.697	0.431	0.193
Species-environment co.	0.819	0.285	0.380	0.904	0.795	0.862
O.M.	-0.6800	-0.1397	-0.0643	-0.6972	0.2326	-0.0098
$CaCO_3$	**0.4417**	**0.1031**	0.0709	0.4365	-0.1101	0.5429
S.P.	-0.6696	-0.1777	-0.0071	-0.7206	0.2131	0.2234
pH	0.0303	0.0460	0.1642	-0.0154	**-0.1525**	0.0677
HCO_3^-	0.2302	0.0422	-0.0938	0.3782	0.3729	0.0969
SO_4^{-2}	0.1629	0.0202	-0.0817	0.3077	0.3816	0.1271
Ca^{+2}	0.2633	0.0024	-0.1333	0.4237	0.3749	0.2001
Mg^{+2}	0.3421	0.0798	-0.0920	**0.5099**	0.3938	0.1737
Na^+	0.2222	0.0292	-0.1213	0.4235	0.5214	0.1818
K^+	-0.3569	-0.0799	-0.1077	-0.2264	**0.5515**	-0.0031
P	**-0.7012**	**-0.2185**	-0.0078	**-0.7419**	0.2280	0.1622
K	-0.6138	-0.1682	-0.0181	-0.6527	0.2007	0.1460

tion to the adverse climatic conditions and moisture deficiency probably lead to the frequent occurrence of therophytes during the favourable seasons" which supports the present conclusion. On the other hand, inspection of the life form spectrum in relation to habitat types revealed that, at the time in which therophytes are reported in almost all the studied habitats, cryptophytes are the most common in waste lands (Appendix 1). This is compatible with the report of Zahran (1982) who clarified that, cryptophytes are among the most abundant life forms in halophytic vegetation of Egypt. This finding can be explained in term of the plant habit, where almost all of these plants are rhizomatous (*e.g. Cynodon dactylon*, *Juncus rigidus* and *Phragmites australis*), which are believed to be more resistant to decomposition under water submergence. Similar conclusion has been reached by El-Demerdash (1984), Mashaly (1987), Shaltout & Sharaf El-Din (1988) and Shaltout *et al.* (1994).

Abd El-Razik *et al.* (1984) reported that, the dominant perennials in arid desert regions were trees, shrubs (or subshrubs) and perennial herbs. Some of these perennials are

Table 4 – The floristic similarity between the different habitats in the study area. CB = canal banks, CL = cultivated lands, WL = waste lands and SP = sand plains.

Habitats	CB	CL	WL	SP
CB				
CL	.801**			
WL	NS	-.163*		
SP	-.224**	-.182*	NS	
Total number of species	**100**	**97**	**27**	**31**

drought enduring plants in which the photosynthetically and transpiring organs were maintained at nearly constant proportion. In accordance with this report, the composition of life span (Figure 3) in the recognized habitats of the study area (Appendix 1) revealed that, perennials represent majority of recorded species in the sand plains and waste land habitats, whereas annuals are the most common in canal banks and cultivated lands. Abd El-Ghani & Abd El-Khalik (2006) explained these relationships based on the extensive root systems of the trees and shrubs that are capable of utilising water stored at different soil depths; which is further supported based on the present data.

El-Gharably *et al.* (1982) reported an increasing spread of aquatic weeds in the irrigation and drainage canals of the Nile Delta and attributed this finding to some ecological factors *e.g.* increasing pollution from agricultural practices, industrial centers and human activity along canals and drains. In a recent study on macrophytic vegetation in the Nile Delta region, Abd El-Ghani *et al.* (2010) supported such view as they recorded presence of Cu, Fe, Hg and Pb traces in the water samples. They monitored significant levels ($P < 0.001$) of variation in both Hg and Fe concentrations, and attributed it to the industrial activities that took place through many factories, which had disposed such harmful and poisonous elements as waste products to the surrounding Nile water. In the present study, the floristic similarity between recognized habitats (Table 4) revealed a frequent spread of the aquatic weeds in all canals and showed a significant positive correlation between the canal banks and cultivated lands habitats. They are the more diversified habitats with high species richness (Appendix 1). This may be due to the fact that water of irrigation canals may seep the canal borders and hence increase the soil moisture availability. On the other hand, not only the waste lands and sand plains have significant positive correlations with each other, but also they are the least diversified habitats. Thus, the present data are further confirming the reports of El-Gharably *et al.* (1982) and Abd El-Ghani *et al.* (2010).

Ramakrishnan & Singh (1966) and Täckholm (1974) pointed out that, the high ecological amplitude of a certain species could be explained due to presence of ecological races suited to specific habitat conditions and the very effective vegetative spread by runners, in addition to seed production of these species. Shaltout & Sharaf El-Din (1988) supported this view and reported that, the flourishing of some species in many of habitats is related to their great plasticity under different situations. These explanations are strongly supported by the present investigation based on habits of the recorded species in each of the recognized habitats. The species distribution of the study area (Appendix 1) indicated that, some species *e.g. Pluchea dioscoridis, Cynodon dactylon* and *Phragmites australis* have been recorded in all or most of the habitats (*i.e.* have a wide ecological range of distribution) and at the same time they have very effective vegetative spread. On the other hand, because of the adaptations to definite habitats; seventy-nine species (48.2% of the total) demonstrated a certain degree of consistency, where they are exclusively recorded or confined to a certain habitat and do not occur elsewhere. These species are distributed in percentages of 34.44%, 37.72%, 21.32% & 36.08% in each of the canal banks, cultivated lands, waste lands and sand plains, respectively.

Classification of vegetation

Vegetation group A of the present study (Figure 4; Table 1; Appendix 1) is dominated by weed plants with some trees and shrubs. It is characterized by the occurrence of water-loving species and salt-tolerant species. Similar group has previously been recognized by Abd El-Ghani (1998) in southern Sinai; Shaltout & El-Halawany (1992) in the perennial grassy communities of Saudi Arabia; Shaltout *et al.* (1992) in the winter weeds associations in the Nile Delta region. This indicates the considerable homology in soil characteristics and plant distribution in the study area and in such locations.

Group B (Figure 4; Table 1; Appendix 1) is mainly dominating by Halophytic and Helophytic plants. Five growth forms can be distinguished: (a) rhizomatous growth form *e.g. Juncus rigidus*, *Typha domingensis* and *Cyperus laevigatus*; (b) stoloniferous growth form as in *Aeluropus lagopoides* and *Phragmites australis*; (c) non-succulent perennial herb growth form *e.g. Cressa cretica*; (d) non-succulent frutiscents as in *Tamarix nilotica* and *Alhagi graecorum*; (e) succulent frutiscents as in *Zygophyllum simplex*. These data are in accordance with those of Ayyad & El-Ghareeb (1982) and Sheded & Hassan (1998) in connection that, this group has analogues in the northern and southern parts of the Western Desert of Egypt, respectively.

Group C (Figure 4; Table 1; Appendix 1) is mainly dominated by xerophytic plants especially *Haloxylon salicornicum* and characterized by a frequent distribution of *Alhagi graecorum* in each of waste land and sand plain habitats. Twenty-two species showed a certain degree of fidelity, they do not occur in other groups *e.g. Zygophyllum album, Panicum turgidum, Fagonia Arabica* and *Erodium laciniatum*. In general, distribution of this group in the study area is consistent with reports of Batanouny (1979) and Zahran & Willis (1992) regarding the distribution of such plants in waste land and sand plain habitats. The frequent distribution of *Alhagi graecorum* might support the reports of Kassas (1952) and Girgis (1972) whose considered this species as a groundwater-indicating plant, which needs further investigation.

Soil characteristics

All of the measured soil variables (Table 1); except pH; showed highly significant differences between the three vegetation groups. The correlations between the measured soil variables (Table 2) indicated that calcium, magnesium, $CaCO_3$ and potassium cations had the highest number of correlations. Soil texture (coarse and fine sand, silt and clay) showed highly significant positive or negative correlations with each other, and with organic matter, $CaCO_3$, Mg^{+2}, K^{+}, nitrogen, phosphorus and available potassium. Calcium, magnesium and $CaCO_3$ correlated negatively with organic matter, saturation percentage, N, P and K. Also significant negative correlations are occurred between the other soil variables such as chlorides with potassium, and saturation percentage with E.C., chlorides and sodium.

Ordination of plots

The species-environment correlation is high (0.819 and 0.285) for DCA axes 1 and 2 (Figure 5) indicating that, the species data are strongly related to the measured environmental variables. Draw scores of DCA axis 1 and 2 are positively correlated (0.4417, 0.1031 respectively) with $CaCO_3$, and negatively (− 0.7012, − 0.2185 respectively) with phosphorus. The vegetation groups identified in the present study area are well segregated along the DCA axis one; which reflects the calcium carbonates, fertility and species diversity gradients. It also are represented the gradient of human interference, where the full man-made vegetation (canal banks and cultivated lands) occupied the left negative end of this gradient, where the less disturbed vegetation (waste moist lands) is in the middle and no man-made vegetation (sand plains) is in the right positive end. This finding agrees with those of previous studies on habitats types and plant communities in Nile Delta region (Shaltout & Sharaf El-Din 1988) and in Sharkiya Governorate (Abd Alla 2007).

Soil-vegetation relationships

In CCA data (Figure 6), the successive decrease of Eigenvalues of the four CCA axes (0.697, 0.431, 0.193 and 0.173 for axes 1, 2, 3 and 4, respectively) reveals a well-structured data set Table (3). The species-environment correlations are higher for the four axes, explaining 67.5% of the cumulative variance. Due to high inflation factor of coarse sand, fine sand, silt, clay, E.C., chlorides and nitrogen, they are removed from the analysis. Therefore, CCA is performed using 12 soil variables (organic matter, $CaCO_3$, saturation percentage, pH, bicarbonates, sulphates, calcium, magnesium, sodium, potassium cations, phosphorus and potassium). These results reveal an association between vegetation and the measured soil variables presented in the biplot. From the inter-set correlations of the soil variables and the first three axes of CCA, it can be inferred that CCA axis 1 is positively correlated with magnesium and negatively with phosphorus, so this axis can be interpreted as magnesium-phosphorus gradient, while the second axis is defined by K^+ and pH. A test for significance with an unrestricted Monte Carlo permutation test (499 permutation) for the Eigenvalue of axis 1 found to be significant ($P = 0.002$), indicating that the observed patterns did not arise by chance. The ordination diagram produced by CCA in Figure (7) showed that the pattern of ordination is similar to that of the floristic DCA (Figure 5), with most of the plots remaining in their respective vegetation groups. Clearly, weed plants group (Group A) is highly associated with organic matter, phosphorus, potassium, saturation percentage, potassium cations and pH; the Halo/Helophytic plants (group B) with bicarbonates, sulphates, calcium, magnesium and sodium, while the xerophetic plants (group C) with $CaCO_3$ and pH.

Species diversity and environment

Species diversity (species richness and Shannon's index) varied significantly among the recognized vegetation groups (Table 2). Generally, weed plants showed the highest species richness (24.44 ± 3.92) and Shannon's index (3.18 ± 0.16), whereas xerophetic plants showed the lowest species richness (6.35 ± 3.30) and Shannon's index (1.66 ± 0.73). Regarding the effect of soil variables on the species diversity (Table 3), both species diversity measurements showed similar trend: positive correlation with each other, and with silt, clay, organic matter, saturation percentage, potassium cations, nitrogen, phosphorus and potassium, and negative correlation with coarse sand, fine sand, $CaCO_3$, E.C., bicarbonates, chlorides, calcium, magnesium and sodium.

Nilsson *et al.* (1991) stated that, increasing habitat heterogeneity increases species diversity. Comparison of the soil characters in different habitats of the study area indicates that silt, clay, organic matter, nitrogen, phosphorus and potassium increases in the canal banks and cultivated lands *i.e.* dominated by weed plants group (A), while decrease in the waste lands *i.e.* Halo/Helophytic plants group (B) and sand plains *i.e.* xerophytic plants group (C). Thus, the high species diversity and species richness of group A is related to the increase of soil fertility (organic matter, nitrogen, phosphorus and potassium). On the other hand, the low species richness of waste lands and sand plains may due to the fact that, most of its species are highly specific to these habitats of the severe environment (*e.g.* severe aridity and salinity). Whittaker (1972) and Poole (1974) reported that, communities occurring in severe environment have a good fit to the geometric series of the niche-preemption that characterizes the communities with low species diversity, which is further support the present inference. Shaltout (1985) had reached a similar conclusion concerning the communities under stress of aridity and salinity in the Western Mediterranean region of Egypt.

Conclusion

It can be concluded that clustering, ordination and statistical approaches in this paper were useful in establishing a scale for classification of vegetation in relation to soil characteristics in the most representative habitats of Qalyubia governorate. This study confirmed the correlation between spread of weeds and pollution that occurs indirectly due to increasing of urbanization activities on the cultivated lands. Most of the reported weed plants herein were water-loving and salt-tolerant species. All of the measured soil variables except pH; showed highly significant differences and the correlations between the measured soil variables indicated that calcium, magnesium, $CaCO_3$ and potassium cations had the highest number of correlations in affecting the plant distribution. Furthermore, the recognized vegetation groups were affected by species diversity gradients and the gradient of human interference. The weed plants showed the highest species richness and diversity in contrary to xerophytic plants that showed the lowest values. The high species richness and diversity of the weed plants was related to the increase of soil fertility (organic matter, nitrogen, phosphorus and potassium). The low species richness and diversity of waste lands and sand plains habitats was due to the fact that, most of their species were highly specific the severe conditions (*e.g.* aridity and salinity). Most of these habitats included fragile communities of the urgent need for restoration and conservation.

Appendix 1 – List of vascular plant species recorded in the study area. Life forms: Ph = phanerophytes, Ch = chamaephytes, H = hemicryptophytes, Cr = cryptophytes, Th = therophytes, P = parasites. Habitats abbreviations: CB = canal banks, CL = cultivated lands, WL = waste lands, SP = sand plains. Figures represent the presence values (P%) for each species.

Species		Life-span	Life-form	Habitats			
				CB	CL	WL	SP
Azollaceae	*Azolla filiculoides* Lam.	Ann.	Cr	5	0	0	0
Marsileaceae	*Marsilea aegyptiaca* Willd.	Per. Herb	H	5	0	0	0
Casuarinaceae	*Casuarina stricta* Miq. ex Aiton	Tree	Ph	20	0	0	0
Salicaceae	*Salix mucronata* Thunb.	Tree	Ph	35	0	0	0
	Salix tetrasperma Roxb.	Tree	Ph	30	0	0	0
Moraceae	*Morus alba* L.	Tree	Ph	15	0	0	0
Urticaceae	*Urtica urens* L.	Ann.	Th	10	36.6	0	0
Polygonaceae	*Calligonum polygonoides* L.	Shrub	Ph	0	0	0	10
	Emex spinosa (L.) Campd.	Ann.	Th	0	6.6	0	5
	Persicaria salicifolia (Brouss. ex Willd.) Assenov	Per. Herb	Cr	35	3.3	0	0
	Rumex dentatus L.	Ann.	Th	70	50	0	0
Molluginaceae	*Glinus lotoides* L.	Ann.	Th	0	0	0	5
Aizoaceae	*Trianthema portulacastrum* L.	Ann.	Th	45	70	0	0
Portulacaceae	*Portulaca oleracea* L.	Ann.	Th	65	80	0	0
Caryophyllaceae	*Silene rubella* L. var. *rubella*	Ann.	Th	15	20	0	0
	Stellaria media (L.) Vill.	Ann.	Th	45	26.6	0	0
	Polycarpaea repens (Forssk.) Asch. & Schweinf.	Per. Herb	H	0	0	0	5
Chenopodiaceae	*Beta vulgaris* L. subsp. *maritima* (L.) Arcang.	Ann.	Th	35	40	0	0
	Chenopodium ambrosioides L.	Ann.	Th	5	0	0	0
	Chenopodium murale L.	Ann.	Th	50	73.3	0	0
	Chenopodium album L.	Ann.	Th	25	60	0	0
	Bassia muricata (L.) Asch.	Ann.	Th	0	0	0	20
	Bassia indica (Wight) A. J. Scott	Ann.	Th	0	0	30	15
	Haloxylon salicornicum (Moq.) Bunge ex Boiss.	Shrub	Ch	0	0	0	95
	Cornulaca monacantha Delile	Shrub	Ch	0	0	0	55
Amaranthaceae	*Amaranthus hybridus* L.	Ann.	Th	35	40	0	0
	Amaranthus lividus L.	Ann.	Th	25	43.3	0	0
	Alternanthera sessilis (L.) DC.	Ann.	Cr	15	0	0	0
Ranunculaceae	*Ranunculus sceleratus* L.	Ann.	Th	15	0	0	0
	Ranunculus marginatus Urv.	Ann.	Th	0	3.3	0	0
Ceratophyllaceae	*Ceratophyllum demersum* L.	Per. Herb	Cr	5	0	0	0
Fumariaceae	*Fumaria densiflora* DC.	Ann.	Th	0	3.3	0	0
Cruciferae	*Sisymbrium irio* L.	Ann.	Th	0	3.3	0	0
	Rorippa palustris (L.) Besser	Ann.	Th	25	6.6	0	0
	Brassica tournefortii Gouan	Ann.	Th	5	13.3	0	0
	Brassica nigra (L.) Koch	Ann.	Th	15	13.3	0	0
	Eruca sativa Mill.	Ann.	Th	0	16.6	0	0
	Raphanus sativus L.	Ann.	Th	10	3.3	0	0
	Lepidium sativum L.	Ann.	Th	0	3.3	0	0
	Coronopus squamatus (Forssk.) Asch.	Ann.	Th	40	50	0	0
	Coronopus didymus (L.) Sm.	Ann.	Th	5	13.3	0	0
	Capsella bursa-pastoris (L.) Medik.	Ann.	Th	30	33.3	0	0
Neuradaceae	*Neurada procumbens* L.	Ann.	Th	0	0	0	5
Leguminosae	*Medicago polymorpha* L.	Ann.	Th	0	6.6	0	0
	Medicago intertexta (L.) Mill.var. *ciliaris* (L.) Heyn	Ann.	Th	20	20	0	0
	Melilotus indicus (L.) All.	Ann.	Th	25	36.6	0	0
	Trifolium resupinatum L.	Ann.	Th	35	13.3	0	0
	Lotus glaber Mill.	Ann.	H	5	3.3	0	0
	Sesbania sesban (L.) Merr.	Tree	Ph	10	3.3	0	0
	Alhagi graecorum Boiss.	Per. Herb	H	0	0	100	5
	Vicia faba L.	Ann.	Th	0	3.3	0	0
	Vicia sativa L.	Ann.	Th	25	6.6	0	0
	Pisum sativum L. subsp. *sativum*	Ann.	Th	0	3.3	0	0
	Acacia nilotica (L.) Delile	Tree	Ph	5	0	0	0
	Acacia tortilis (Forssk.) Hayne	Tree	Ph	0	0	0	15
Oxalidaceae	*Oxalis corniculata* L.	Per. Herb	Cr	60	73.3	0	0
Geraniaceae	*Geranium dissectum* L.	Ann.	Th	0	3.3	0	0
	Erodium laciniatum (Cav.) Willd.	Ann.	Th	0	0	0	5
Zygophyllaceae	*Fagonia arabica* L.	Shrub	Ch	0	0	0	10
	Zygophyllum simplex L.	Ann.	Th	0	0	10	0
	Zygophyllum album L. f.	Shrub	H	0	0	0	25

Species		Life-span	Life-form	Habitats			
				CB	CL	WL	SP
	Tribulus bimucronatus Viv. var. *bispinulosus* (Kralik) Hosni	Ann.	Th	0	0	0	5
Euphorbiaceae	*Ricinus communis* L.	Per. Herb	Ph	15	0	0	0
	Euphorbia forsskaolii J.Gay	Ann.	H	5	13.3	0	0
	Euphorbia heterophylla L.	Ann.	Th	15	10	0	0
	Euphorbia helioscopia L.	Ann.	Th	35	56.6	0	0
	Euphorbia peplus L.	Ann.	Th	30	66.6	0	0
Tiliaceae	*Corchorus olitorius* L.	Ann.	Th	0	6.6	0	0
Malvaceae	*Malva parviflora* L.	Ann.	Th	65	63.3	0	0
	Sida alba L.	Ann.	Th	0	6.6	0	0
	Hibiscus trionum L.	Ann.	Th	0	10	0	0
Tamaricaceae	*Tamarix nilotica* (Ehrenb.) Bunge	Shrub	Ph	0	0	60	35
Myrtaceae	*Eucalyptus camaldulensis* Dehnh.	Tree	Ph	20	0	0	0
Onagraceae	*Ludwigia stolonifera* (Guill.& Perr.) P. H. Raven	Per. Herb	Cr	0	0	20	0
Umbelliferae	*Ammi majus* L.	Ann.	Th	15	16.6	0	0
	Petroselinum crispum (Mill.) A. W. Hill	Bi.	Th	0	3.3	0	0
	Anethum graveolens	Bi.	Th	5	10	0	0
Primulaceae	*Anagallis arvensis* L. var. *arvensis*	Ann.	Th	20	16.6	0	0
	Anagallis arvensis L. var. *caerulea* Gouan	Ann.	Th	65	70	0	0
Asclepiadaceae	*Cynanchum acutum* L. subsp. *acutum*	Per. Herb	H	5	33.3	25	30
Convolvulaceae	*Convolvulus lanatus* Vahl	Shrub	Ph	0	0	0	55
	Convolvulus arvensis L.	Per. Herb	H	70	80	0	0
	Ipomoea carnea Jacq.	Shrub	Ch	3.3	0	0	0
	Ipomoea purpurea (L.) Roth	Ann.	H	0	5	0	0
	Cressa cretica L.	Ann.	H	0	0	20	0
Cuscutaceae	*Cuscuta pedicellata* Ledeb.	Ann.	P	5	6.6	0	0
Boraginaceae	*Heliotropium digynum* (Forssk.) Asch. ex C. Chr.	Per. Herb	Ch	0	0	0	45
	Arnebia hispidissima (Lehm.) DC.	Ann.	Ch	0	0	5	0
	Moltkiopsis ciliata (Forssk.) I. M. Johnst.	Shrub	Ch	0	0	0	30
	Echiochilon fruticosum Desf.	Shrub	Ch	0	0	0	55
Verbenaceae	*Lantana camara* L.	Shrub	Ph	5	3.3	0	0
	Phyla nodiflora (L.) Greene	Per. Herb	H	10	0	0	0
	Verbena officinalis L.	Per. Herb	Th	15	0	0	0
Labiatae	*Mentha sativa* L.	Per. Herb	Cr	20	6.6	0	0
	Mentha longifolia (L.) Huds. subsp. *typhoides* (Briq.) Harley	Per. Herb	Cr	20	0	0	0
	Lamium amplexicaule L.	Ann.	Th	30	43.3	0	0
Solanaceae	*Solanum nigrum* L.	Ann.	Ch	20	43.3	0	0
	Physalis angulata L.	Ann.	Ch	0	3.3	0	0
	Withania somnifera (L.) Dunal	Shrub	Ch	5	6.6	0	0
	Datura innoxia Mill.	Ann.	Th	0	3.3	0	0
Scrophulariaceae	*Bacopa monnieri* (L.) Pennell	Per. Herb	Cr	0	0	5	0
	Veronica polita Fr.	Ann.	Cr	20	40	0	0
	Veronica anagallis-aquatica L.	Per. Herb	Cr	30	3.3	0	0
Orobanchaceae	*Orobanche crenata* Forssk.	Ann.	P	0	3.3	0	0
Plantaginaceae	*Plantago major* L.	Per. Herb	H	70	33.3	0	0
Compositae	*Silybum marianum* (L.) Gaertn.	Bi.	H	0	0	5	0
	Centaurea calcitrapa L.	Bi.	Ch	0	0	0	5
	Pluchea dioscoridis (L.) DC.	Shrub	Ph	30	6.6	60	5
	Conyza bonariensis (L.) Cronquist	Ann.	Th	5	0	35	0
	Pseudognaphalium luteoalbum (L.) Hilliard & B. L. Burtt	Ann.	Th	10	0	0	0
	Pulicaria undulata (L.) C. A. Mey.	Shrub	Ch	0	0	10	0
	Xanthium strumarium L.	Ann.	Th	5	40	0	0
	Eclipta prostrate (L.) L.	Ann.	Th	35	13.3	0	0
	Galinsoga parviflora Cav.	Ann.	Th	0	3.3	0	0
	Bidens pilosa L.	Ann.	Th	35	43.3	0	0
	Senecio glaucus L. subsp. *coronopifolius* (Maire) C. Alexander	Ann.	Th	0	0	15	10
	Cichorium endivia L. subsp. *divaricatum* (Schousb.) P. D. Sell	Ann.	Th	40	50	0	0
	Launaea nudicaulis (L.) Hook. f.	Per. Herb	H	0	0	5	10
	Sonchus maritimus L.	Per. Herb	Ch	0	0	5	0
	Sonchus oleraceus L.	Ann.	Th	75	66.6	0	0
Pontederiaceae	*Eichhornia crassipes* (C. Mart.) Solms	Per. Herb	Cr	10	0	0	0
Juncaceae	*Juncus acutus* L.	Per. Herb	Cr	0	0	25	0
	Juncus rigidus Desf.	Per. Herb	Cr	0	0	65	0

Species		Life-span	Life-form	Habitats			
				CB	CL	WL	SP
Gramineae	*Lolium perenne* L.	Ann.	Th	0	3.3	0	0
	Poa annua L.	Ann.	Th	55	53.3	0	0
	Avena fatua L.	Ann.	Th	15	26.6	0	0
	Avena sterilis L.	Ann.	Th	5	6.6	0	0
	Rostraria cristata (L.) Tzvelev	Ann.	Th	5	0	0	0
	Phalaris minor Retz.	Ann.	Th	25	13.3	0	0
	Ammophila arenaria (L.) Link	Per. Herb	Cr	0	0	0	15
	Polypogon monspeliensis (L.) Desf.	Ann.	Th	40	23.3	0	0
	Polypogon viridis (Gouan) Breistr.	Per. Herb	H	25	16.6	0	0
	Bromus catharticus Vahl	Ann.	Th	15	16.6	0	0
	Arundo donax L.	Per. Herb	Cr	15	0	10	0
	Phragmites australis (Cav.) Trin. ex Steud.	Per. Herb	Cr	15	0	65	5
	Stipagrostis plumose (L.) Munro ex T. Anderson	Per. Herb	Th	0	0	0	15
	Aeluropus lagopoides (L.) Trin. ex Thwaites	Shrub	Cr	0	0	5	0
	Leptochloa fusca (L.) Kunth	Per. Herb	Cr	5	3.3	0	0
	Dinebra retroflexa (Vahl) Panz.	Ann.	Th	5	23.3	0	0
	Eleusine indica (L.) Gaertn.	Ann.	Th	10	3.3	0	0
	Dactyloctenium aegyptium (L.) Willd.	Ann.	Th	0	6.6	0	0
	Desmostachya bipinnata (L.) Stapf	Per. Herb	Cr	15	0	60	0
	Cynodon dactylon (L.) Pers.	Per. Herb	Cr	60	56.6	20	0
	Panicum turgidum Forssk.	Per. Herb	Cr	0	0	0	20
	Panicum repens L.	Per. Herb	Cr	70	6.6	0	0
	Echinochloa crusgalli (L.) P. Beauv.	Ann.	Th	20	33.3	0	0
	Echinochloa colona (L.) Link	Ann.	Th	65	53.3	0	0
	Paspalum distichum L.	Per. Herb	Cr	75	26.6	0	0
	Setaria pumila (Poir.) Roem. & Schult.	Ann.	Th	35	26.6	0	0
	Paspalidium geminatum (Forssk.) Stapf.	Per. Herb	Cr	15	10	0	0
	Digitaria sanguinalis (L.) Scop.	Ann.	Th	80	73.3	0	0
	Cenchrus ciliaris L.	Per. Herb	H	0	0	0	15
	Imperata cylindrica (L.) Raeusch.	Per. Herb	H	5	6.6	0	0
	Sorghum halepense (L.) Pers.	Per. Herb	Cr	0	3.3	0	0
	Sorghum virgatum (Hack.) Stapf	Ann.	Cr	0	6.6	0	0
	Dichanthium annulatum (Forssk.) Stapf	Per. Herb	Cr	20	10	0	0
Palmae	*Phoenix dactylifera* L.	Tree	Ph	0	0	0	5
Lemnaceae	*Lemna gibba* L.	Per. Herb	Cr	10	0	0	0
Typhaceae	*Typha domingensis* (Pers.) Poir. ex Steud.	Per. Herb	Cr	5	0	30	0
Cyperaceae	*Cyperus alopecuroides* Rottb.	Per. Herb	Cr	15	0	15	0
	Cyperus articulatus L.	Per. Herb	Cr	0	0	5	0
	Cyperus rotundus L.	Per. Herb	Cr	65	43.3	0	0
	Cyperus difformis L.	Ann.	Th	0	30	0	0
	Cyperus laevigatus L.	Per. Herb	Cr	0	0	50	0

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