CATRINA (2024), 29(1): 25-38

Exploring Ruderal Vegetation Dynamics and Site Factors in Managed Habitats of North East Cairo, Egypt

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ABSTRACT

In two new urban cities established in the Egyptian eastern desert, the floristic/soil relationship of representative habitats were evaluated. Overall, sixty-six plots were surveyed and thirteen soil parameters were analyzed in four principle habitats (house gardens, lawn lands, waste grounds and bordering desert) from inner cities toward outskirts. Generally, 138 cultivated plants, 63 weed species, 44 xerophytic plants and 4 wild shrubs and trees represented the main flora with total number of 249 plant species. The greatest diverse habitat was the lawn lands (173 species), house gardens (143 species), then bordering desert (62 species) and the waste grounds (39 species). Sixteen plant communities were recognized in the four habitats under investigation, and their controlling environmental variables were analyzed. The Canonical Correspondence Analysis (CCA) yielded analogous pattern to that of the Detrended Correspondence Analysis (DCA), confirming that clay, pH, organic matter, bicarbonates and calcium are highly associated with weed/cultivated plant communities in the human-disturbed habitats; whereas, pH, organic matter, potassium and chlorides are highly associated with the halo/helophytes communities in the waste grounds, and clay-sand gradient with the xerophytes communities in the bordering desert.
Keywords: Desert cities; Environmental heterogeneity; Species diversity; Urban biodiversity; Urban ecology.

INTRODUCTION

Human infrastructure such as electricity, water, drainage, residential and commercial building, roads, and opened area needed for waste disposal dominated urban landscapes. Occasionally, half of the urban land area is covered by gardens, parks, playgrounds and lawns (Baines, 1995). Owing to urbanization and rapid development in cities, biodiversity conservation has become challenging task (Tsai, 1999). Climate, soil, human impacts, and other variables distinguish urban areas from non-urban ones; the interactions of these factors make over distinctive urban ecosystem. In addition, Sukopp (1990) showed that there is a clear connection between the environment and vegetation in metropolitan areas, whether or not they are industrialized. Consequently, the cities have to be regarded as distinct ecosystem with habitats and floristic compositions unique to urban settings.

Egypt's population continues to increase annually by about 1.5 million people. The old urban areas, already occupied, so the new cities were constructed in the bordering desert to redistribution of population. Habitat loss and fragmentation- most notably caused by urban and agricultural development- contribute to a reduction of biodiversity beside other factors such as pollution, the spread of alien/invasive species and climate conditions (Rogan and Lacher, 2018). Various studies of urban vegetation highlighted fragmentation (e.g. Stenhouse, 2004; Guirado *et al.*, 2006). Seiler (2001) clarified that habitat destruction, disturbances, and pollution resulted from urbanization are the main threats for native plant species. The ecosystem of urbanizing locations comprise a variety of species and habitats from the decorative and spontaneous flora, therefore the concept urban vegetation point to wild and cultivated plant species inhabit in cities (Knapp *et al*., 2012). On the other side, Smith *et al.* (2006) showed that urban green areas contribute to conservation of urban diversity as it provide sustenance for various other species. Consequently, synanthropic flora is defined as that which is significantly impacted by human activities; particularly in cities and towns; and it is important topics in urban ecology (Sukopp, 2004).

Despite the increasing recognition of the value of landscape in the new urbanizing areas, most of the research focusing on green spaces in the urban environment has been conducted in North America, Europe and East Asia (e.g. Ken, 2009; Stewart *et al*., 2009; Nagendra and Gopal, 2010). The situation in Egypt is not different from other developing countries. There is a dearth of literature on urban habitat (Abd El-Ghani *et al*, 2015a); especially in new settlements. Danin *et al*. (1982) researched the synanthropic plant communities in the first generation cities (oldest established from1977 to 1982) built on sandy regosol soils in Northeastern Sinai. Abd El-Ghani *et al*. (2011a; 2015b) investigated habitat-vegetation heterogeneity of industrial cities within the urbanizing desert ecosystem. Therefore, the goal of this investigation was to highlight the diversity and distribution of urban vegetation in the recently established cities (second and third-generation cities), characterize the habitats of urbanized desert ecosystems, and to assess the soil-vegetation relationship, and explore the underlying interactions between urbanization (human-disturbance), floristic composition and site conditions.

MATERIALS AND METHODS

Study Area

The present study will focus on two new urban areas

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(cities) which have been established in and around the metropolitan of Cairo city, in the northern region of the Egyptian's Eastern Desert (Figure 1) to alleviate the congestion in downtown Cairo. The first settlement established in 1982 (Al-Obour) is one of the second generation of new cities, lies west of the Cairo-Belbeis desert road and south of Cairo-Ismailia road in Qalyubia Governorate, about 35 km north-east of Cairo at 30°12′18″ N and 31°27′27″ E. The residential block occupied 18.81 km2, out of a total area (52.43 km2), with an industrial area of 15.73 km2. The second settlement is the New Cairo which considered a city of the third-generation that established in the year 2000, located between the Katameya-Ain Sokhna desert road and the Cairo-Suez desert road at 30°3′ N and 31°47′ E. It is one of the largest new cities in Egypt, with an estimated area of about 321.82 km2. The city's residential and industrial activities represent 173.91 and 4.86 km2, respectively.

The study areas located within the hyper arid desert climate of high evaporation rate, high temperature and very low and unpredictable rainfall (Ayyad and Ghabbour, 1986). Average rainfall is characterized by its scantiness and its variability; it only happens during winter months and is owing to random cloudbursts, certain years have rainfall above 50 mm and others are completely dry. According to the climatic data over the study period in the nearest metrological station (10th Ramadan Station) to Al-Obour City, the average of maximum temperature varied between 36 ˚C in July and 17.9 in January, while the average of minimum temperature ranged from 20.3 ˚C in august and 7.8 ˚C in January, and the mean annually recorded temperature was 20.9 ˚C. While, the mean annually temperature in the New Cairo city (El-Katamia Station) was 20.8 ˚C, the average of maximum temperature varied from 34.7 ˚C in July and 17.8 ˚C in January, and the average of minimum temperature ranged between 20.7 ˚C in August and 7.2 ˚C in January. The rainfall average was low; the rainy season was limited from November to February, and the maximum amount of rainfall precipitated in December (7 mm and 6.2 mm of Al-Obour and New Cairo cities, respectively) with the possibility of a thunderstorm in April.

Field work and floristic analysis

Periodically from 2019 through April 2021, four field trips were conducted to the new cities under investigation. Sixty-six sample plots (20 x 20 m) were selected randomly in various regions for recording; as much as possible; distribution and diversity of plant species. Generally, four main habitats were considered: 1- the lawn lands (L), a pieces of ground cultivated with grasses and other tolerant plants for recreational and aesthetic purpose; and represent essential element of the interaction between natural and urban regions; 2- the house gardens (Hg), area of land adjacent to residential building where ornamentals, fruits and vegetables are planted (Javier, 1988); 3- the waste grounds (W), unoccupied or abandoned zone is not or no longer used and may be saturated with drainage water; 4- the bordering desert; (D), sandy arid or semi-

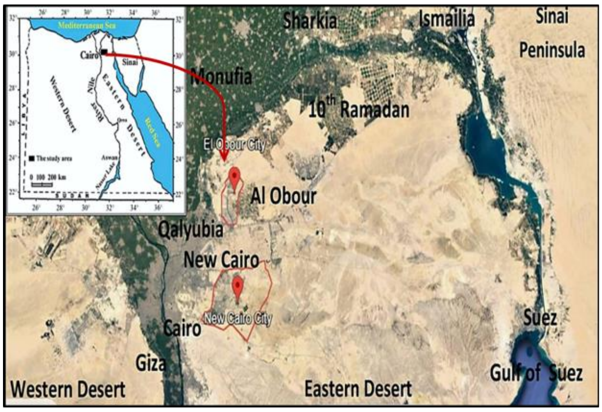

Figure (1): Satellite image of the two urbanized cities (represented by red dots), under investigation in North East Cairo, Egypt.

arid region close to urban cities and distinguished by frequent droughts and low precipitation. The studied plots were distributed as follows: 17 lawn lands, 17 house gardens, 15 waste grounds and 17 bordering desert. Specimens were identified at Cairo University herbaria (CAI) and the Orman Botanical Garden. According to Täckholm (1974) and Boulos (1995-2005 and 2009) nomenclature was carried out and revised using websites (http://www.tropicos.org/) and (http://www.theplantlist.org/).

Soil analysis

For each stand, three soil samples were collected from a depth of 0 to 50 cm. The samples were then mixed together to obtain a composite sample. Subsequently, the mixed sample was air-dried and passed through a 2 mm sieve to remove any debris, ensuring it was ready for chemical and physical analysis. Soil texture was determined using the international pipette method. The quantification of organic matter was performed using the Walkley-Black method (1934). To measure the chemical variables of the soil, a soil/water extract was prepared by mixing soil with water at a ratio of 1:5 (w/v). The pH of the extract was measured using a pH meter (Model Lutron pH 206). Electric conductivity was measured using a conductivity meter (Model Corning, NY, 16542, USA). The concentrations of chlorides and bicarbonates in the soil were determined using titration methods against $AgNO_3$ (0.05 N; Davey and Bembrick, 1969) and HCl (0.1 N; Allen *et al.*, 1974), respectively. Sulfate content was estimated using a turbidimetric technique with a spectrophotometer (Model 1200) following the method described by Bardsley and Lancaster (1965). The determination of potassium and sodium concentrations in the soil was conducted using the flame photometer technique. However, magnesium and calcium concentrations were determined through titration methods with EDTA (0.01 N; Jackson, 1967).

Data analysis

Data analysis was performed using various computer software packages for statistical and multivariate analysis, as well as ordination techniques. The software used included PC-Ord (McCune and Mefford, 1999; ver. 5), CANOCO (Lepš and Šmilauer, 2003; ver. 4.5), and SPSS (SPSS, 1999; ver. 10.0). A floristic absence/presence dataset consisting of 249 species in 66 plots was classified using Ward's method (Orlóci, 1978) after eliminating species reported in only one sample plot (F<25%). Detrended Correspondence Analysis (DCA) was employed to identify the main gradients influencing the distribution of species. Following the exclusion of electric conductivity (EC) due to high inflation factor, the remaining 12 measured soil factors were included in Canonical Correspondence Analysis (CCA). The significance of soil variables was determined using intra-set correlations from CCA through a Monte Carlo permutation test (499 permutations; Ter Braak, 1994). Based on the soil variables, ANOVA was conducted to examine significant variations between the resulting vegetation groups (Sokal and Rohlf, 1981). The species diversity within each group was assessed by calculating the average number of species per sampling plot (species richness, SR) and the Shannon-Wiener diversity index (H'; Pielou, 1975).

RESULTS

Floristic features

In the study area, a total of 249 plant species were documented, representing 64 families and 189 genera. The highest number of species were observed in Asteraceae (23 species), Poaceae (22 species), and Fabaceae (19 species), followed by Brassicaceae, Euphorbiaceae, and Moraceae (12 species each). Arecaceae and Chenopodiaceae were also notable with 11 species each. These families collectively accounted for approximately 48.9% of the overall flora. The remaining families were represented by fewer than nine species, with 46 families having 1-3 species each, such as Asclepiadaceae, Caricaceae, Caryophyllaceae, Neuradaceae, and Urticaceae. *Ficus* (11 species) emerged as the most species-rich genus, followed by *Euphorbia* (6 species), and *Chenopodium*, *Plantago*, and *Zygophyllum* (3 species each). When analyzing the growth form distribution, it was observed that woody perennials (trees and shrubs) constituted the majority, accounting for 50.6% of the species. Perennial herbs represented 25.7% of the flora, while annuals made up 23.7%. The herbaceous plants comprised 123 species belonging to 39 families.

The recorded species were distributed as follow: 187 species in Al-Obour city and 220 species in New-Cairo city, of which one hundred and fifty-eight species were listed in the two investigated cities such as *Amaranthus lividus*, *Bassia indica*, *Bidens pilosa*, *Calotropis procera*, *Chenopodium album*, *Cynodon dactylon*, *Zilla spinosa* and *Zygophyllum simplex*, while 91 species were found in a city and were not present in the other. Twenty-nine species were confined to Al-Obour (e.g. *Alhagi graecorum*, *Aeluropus lagopoides*, *Calligonum polygonoides*, *Eremobium aegyptiacum*, *Fagonia brugieri* and *Senna italica*), and 62 species of New-Cairo city (e.g. *Arundo donax*, *Anthemis melampodina*, *Atriplex dimorphostegia*, *Deverra tortuosa*, *Diplotaxis acris*, *Diplotaxis harra* and *Ochradenus baccatus*.

A floristic comparison between the recorded species in the three new cities included 10th Ramadan (Turky, 2009), Al-Obour and New-Cairo Cities (1st, 2nd and 3rd generation cities, respectively) located in Eastern Desert appeared a considerable change in the number of species (Table 1). The highest species richness observed in the New-Cairo settlement (220 species), whereas Turky (2009) recorded the lowest number (157 species) in 10th Ramadan City. The Pearson's index of similarity between the floristic compositions of different studied cities showed significant positive correlation between three generations (Table 2).

Table (1): Urban profile of new studied cities, including data on residential and industrial areas, as well as the number of inhabitants and recorded plant species (Central Agency for Public Mobilization and Statistics, Egypt, 2021).

Studied Cities	Urban Profile				Number of recorded species
	Establishment year	Industrial area (%)	Residential area %	Inhabitant number	
10th Ramadan	1977	49.2	39	1.500.000	157
Al-Obour	1982	30	35.78	1.436.000	187
New-Cairo	2000	1.7	54	200	220

Table (2): Pearson's coefficient of similarity between cities of three generations

Studied Cities	10th Ramadan (1^{St†})	El-Obour (2^{nd†})	New-Cairo (3^{rd†})
10th Ramadan	1.00		
El-Obour	0.478*	1.00	
New-Cairo	0.354*	0.756**	1.00

† Generation; * r=0.4 to 0.5, weak to moderate correlation; **, high correlation.

Species distribution within habitats

The total number of species recorded throughout the four habitats under study revealed considerable variances. The most species rich habitat was the lawn lands (173 species), then the house gardens (143 species), and the bordering desert (62 species), while the waste grounds had the lowest number (39 species). Obviously, perennials were the dominant growth form in four recognized habitats represented by 74.3% of the total flora. The lawn lands and house gardens recorded the highest percentage of annuals (43 and 31 species, respectively), comparable to bordering desert (28 species) and waste grounds (20 species).

Actually, managed urban habitats (lawns and house gardens) were characterized by having the highest levels of biological variety compared to the vegetation of un-urbanized habitats (bordering desert and waste grounds); they contained ornamentals; e.g. *Rosa multiflora*, *Cassia javanica* subsp. *nodosa*, *Calendula officinalis*, *Thevetia peruviana*, *Pelargonium graveolens*. Also, they included hedge plants; such as *Lantana camara*, *Dodonaea viscosa*, *Hibiscus rosasinensis*, *Duranta erecta*, and *Nerium oleander*, shade trees; e.g. *Ficus benjamina*, *Delonix regia*, *Enterolobium contortisiliquum* and *Bauhinia variegata*, fruit plants; such as *Citrus sinensis*, *C. aurantium*, *Mangifera indica*, *Psidium guajava*, *Vitis vinifera*, *Phoenix dactylifera* and *Carica papaya*. Additionally, they comprised some vegetables; amongst others *Eruca sativa*, *Malva parviflora*, and *Solanum lycopersicum* var. *lycopersicum*, medicinal plants; for example *Mentha sativa*, *Ocimum basilicum* and *Aloe vera*, timber plants (e.g. *Cassia fistula*), fiber plants; such as *Bombax ceiba*, oily plants; as *Olea europaea* var. *europaea*, and poisonous plants (e.g. *Cynanchum acutum* subsp. *acutum* and *Melia azedarach*). Generally, the cultivated plants were 138, followed by weed species (63 species), xerophytic plans (44 species) and wild shrubs and trees (4 species). The lawns and house gardens habitats recorded the highest number of cultivated species among others, meanwhile devoid of xerophytes (Table 3).

Amaranthus hybridus, *Launaea nudicaulis*, *Malva parviflora* and *Pluchea dioscorides* were reported in all habitats, while *Cynodon dactylon*, *Chenopodium murale*, *Phoenix dactylifera* and *Solanum nigrum* were among seventeen recorded species in three habitats. One hundred and three species shared between urbanized areas (e.g. *Ficus microcarpa*, *Sonchus oleraceus*, *Dodonaea viscosa* and *Sisymbrium irio*), ten between un-urbanized habitats (e.g. *Bassia indica*, *Bassia muricata*, *Mesembryan-themum forsskaolii* and *Anabasis setifera*), 6 species only between lawns and bordering desert (e.g. *Plantago ovata*, *Cenchrus ciliaris*, and *Tribulus bimucronatus* var. *bispinulosus*), while *Conyza bonariensis*, *Cynanchum acutum* subsp. *Acu-tum*, *Desmostachya bipinnata* were found in lawn lands and waste grounds. In contrast, 106 species were restricted to a specific habitat and were not recorded in another one; of which 40 cultivated plants and weeds constituted the characteristic species of the lawns habitat (such as *Justicia adhatoda*, *Plantago lagopus*, *Washingtonia robusta* and *Enterolobium contortis-iliquum*), 34 xerophytic species in the bordering desert areas (e.g. *Astragalus eremophilus*, *Zilla spinosa*, *Cornulaca monacantha* and *Echinops spinosus*), 24 ornamental plants in the house gardens (e.g. *Echinoc-actus grusonii*, *Caryota mitis*, *Kigelia Africana* and *Jasminum grandiflorum*) and 8 halo/helophytic species characterized of the waste grounds (e.g. *Juncus rigidus*, *Aeluropus lagopoides* and *Arundo donax*).

Among the four investigated habitats, the Pearson's coefficient was computed using frequency percentages (Table 4). The floristic similarities exhibited negative significant correlations between desert habitats with lawns and house gardens, and significant positive correlation between the lawns and home gardens on one hand, and between the desert habitat and waste grounds in the other.

Table (3): The recorded number of plant species within the four principle existing habitats.

Principle existing Habitats	Plant species recorded			
	Cultivated	Weeds	Xerophytes	Wild (shrub/trees)
All habitats	138	63	44	4
Lawns	112	57	0	4
House gardens	102	40	0	1
Waste grounds	5	20	11	3
Bordering desert	3	15	41	3

Classification of vegetation

The classification of vegetation in the studied habitats involved the use of four data matrices: 44 species recorded in 17 plots in lawn lands, 61 species recorded in 17 plots in house gardens, 23 species recorded in 15 plots in waste grounds, and 45 species recorded in 17 plots in the bordering desert. This analysis resulted in the identification of 16 distinct plant communities or vegetation groups across these habitats (Figure 2). Meanwhile, Figure (3) provides ordination diagrams that illustrate the recorded vegetation groups obtained through cluster analysis using Detrended Correspondence Analysis. These diagrams represent the vegetation composition within the four recognized habitats: In lawns, the soil had the highest concentrations of sulfates, Mg^{+2}, Ca^{+2}, Na^{+} and Hco_3 in group (A); group (B) contained pH, organic matter, sand, bicarbonates and K^{+}; group (C) recorded high values of clay and silt; while group (D) contained pH, sand, sulfates and Mg^{+2} (Table 5). Six leading dominant species (F=100%) were recorded in group (A) such as *Chenopodium murale*, *Cynodon dactylon* and *Malva parviflora*; nine in group (B) e.g. *Ficus microcarpa* and *Sisymbrium irio*; four in group (C) *Cynodon dactylon*, *Ficus microcarpa*, *Sonchus oleraceus* and *Coronopus didymus*; while one species (*Cynodon dactylon*) in group (D).

The mean soil physical-chemical parameters of group (A) in house gardens clarified the highest values of silt, Ca^{+2}, K^{+}, Na^{+}, pH and organic matter. The leading dominant species (F=100%) included *Cynodon dactylon*, *Coronopus didymus*, *Agave americana* and *Poa annua*. Group (B) was characterized by high content of HCO_3, pH and sand, along with dominance of *Cynodon dactylon* and *Bougainvillea spectabilis*. Group (C) had the largest values of clay and silt; in which *Cynodon dactylon* was the dominant species. Group (D) contained clay, Mg^{+2}, Ca^{+2}, bicarbonates and sulfates (Table 5), and comprised 34 dominant species such as *Lantana camara*, *Melilotus indicus* and *Sisymbrium irio*.

Group (A) of the waste grounds was characterized by high values of sulfates and sand, also dominance of *Phragmites australis*. Group (B) had high content of K^{+}, Ca^{+2} and sand, in which four dominant species (F=100%) were recorded included *Mesembryanthemum forsskaolii*, *Launaea nudicaulis*, *Bassia indica*, *Cynanchum acutum* subsp. *acutum*. Group (C) had high values of clay, pH, Cl^{-}, K^{+}, Mg^{+2}, Ca^{+2} and sulfates, as well as *Pluchea dioscorides* and *Tamarix nilotica* were the dominant species. Group (D) recorded high concentrations of clay, silt and organic matter; *Bassia indica*, *B. muricata* and *Amaranthus hybridus* dominant species can be enumerated.

In the bordering desert, Group (A) showed high values of clay and pH, its dominant species was *Anabasis setifera* (F=50%). Group (B) exhibited highest concentrations of sulfates, organic matter and sand. The leading dominant species (F=100%) were *Astragalus eremophilus*, *Bassia indica*, *Erodium glaucophyllum* and *Farsetia aegyptia*. Group (C) had high values of organic matter, silt, pH, Na^{+}, K^{+}, Ca^{+2} and sulfates, and contained ten dominant species, amongst others; *Calotropis procera*, *Forsskaolea tenacissima*, *Convolvulus lanatus*, *Zilla spinosa* and *Zygophyllum coccineum*. Group (D) was characterized by its soil with high concentrations of silt and sand, its dominant species included *Bassia indica* and *Mesembryanthemum forsskaolii*. Notably, the group (C) of desert habitat was confined to new Cairo city; group (A) in the Waste grounds of Al-Obour settlement; and groups (B) and (D) of New Cairo settlement.

Soil characteristics

Soil contents of sand, silt, clay and potassium exhibited insignificant differences among the four habitats (Table 5). The waste grounds had the greatest number of soil factors (8) with significant differences; electrical conductivity, organic matter, sulfates, bicarbonates, chlorides, magnesium, calcium and sodium. On the other hand, soil reaction (pH) showed significant differences in house gardens only, and none of soil factors exhibited significant differences in both bordering desert and lawns habitats.

In terms of the diversity indices, the species richness (SR) clarified significant with lawns and waste grounds, as well as highly significant in each of bordering desert and house gardens. Also, Shannon's index (H′) was significant ($p \leq 0.016$) and highly significant ($p \leq 0.0001$) in lawns and desert habitats, respectively.

Vegetation-soil relationships

Figure (4) illustrates the Canonical Correspondence Analysis (CCA) for the different habitats, displaying their respective plant communities and the corresponding measured environmental factors. Table (5) presents the ordination biplots of the two CCA axes, demonstrating the inter-set correlations of soil factors within the investigated habitats. Additionally, the table includes eigenvalues and species-environment correlations.

In lawns, CCA axis one (organic matter/calcium gradient) associated positively with organic matter and pH, and negatively with calcium and sodium (Table 6). While, axis two (clay/pH gradient) was related positively with clay, silt, organic matter, sodium and potassium and negatively with pH, bicarbonates, magnesium, and sulfates.

In house gardens, the first axis of CCA (clay/pH gradient) related positively with clay, bicarbonates and magnesium, while negatively with pH, potassium, sodium, and sand. The second CCA axis (organic matter / bicarbonates gradient) associated positively with

Table (4): The Pearson's coefficient values represented the correlation between the four investigated habitats.

Habitats	Lawns	House gardens	Waste grounds	Bordering desert
Lawns	1.00			
House gardens	0.733**	1.00		
Waste grounds	0.089	-0.039	1.00	
Bordering desert	-0.194*	-0.287*	0.281*	1.00

* r=0.2 to 0.5, very weak to moderate positive or negative correlation; **, high correlation.

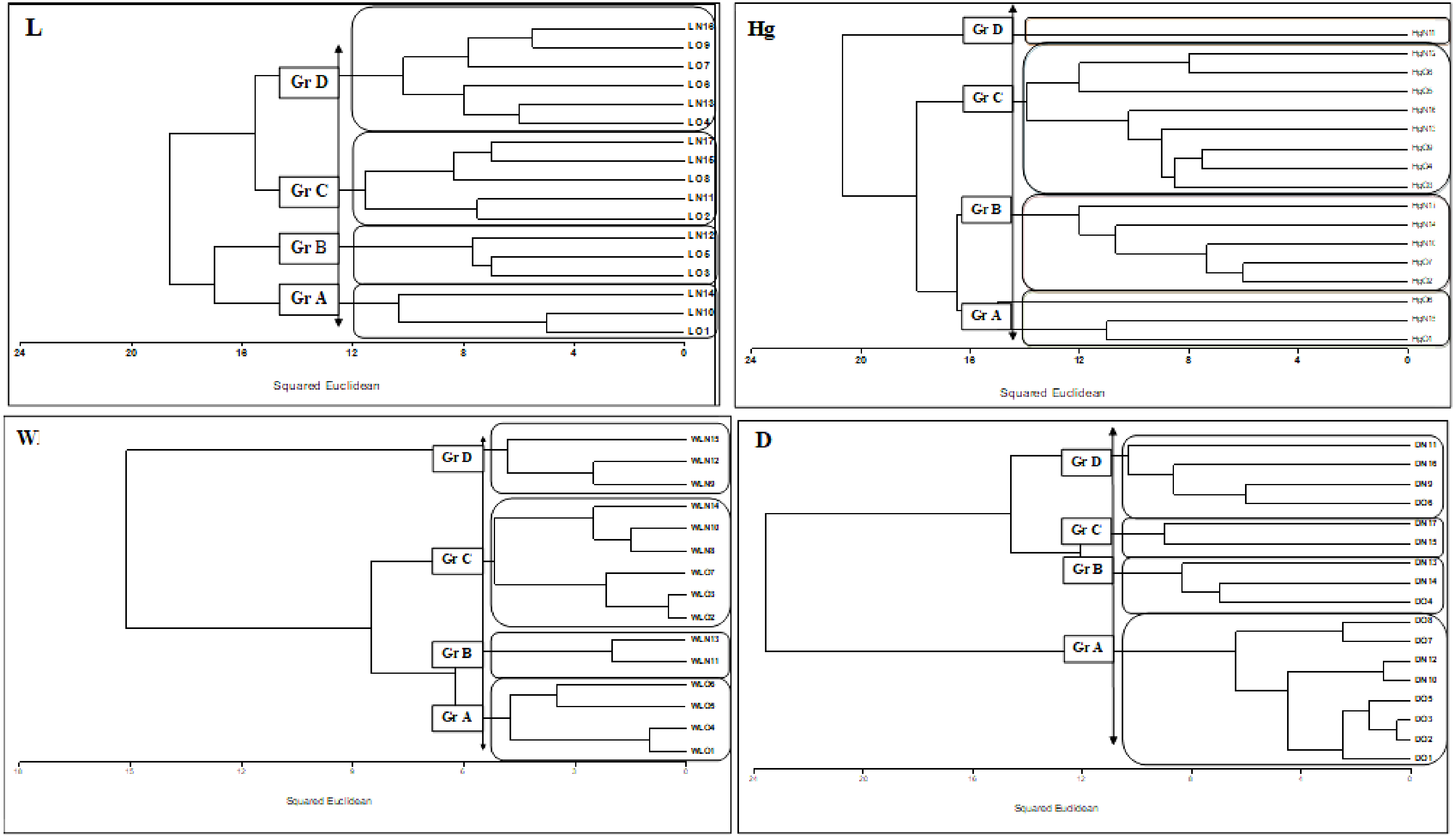

Figure (2): The yielded vegetation groups (16) from cluster analysis of investigated habitats. L, Lawn lands; Hg, House gardens; W, Waste grounds and D, Bordering desert.

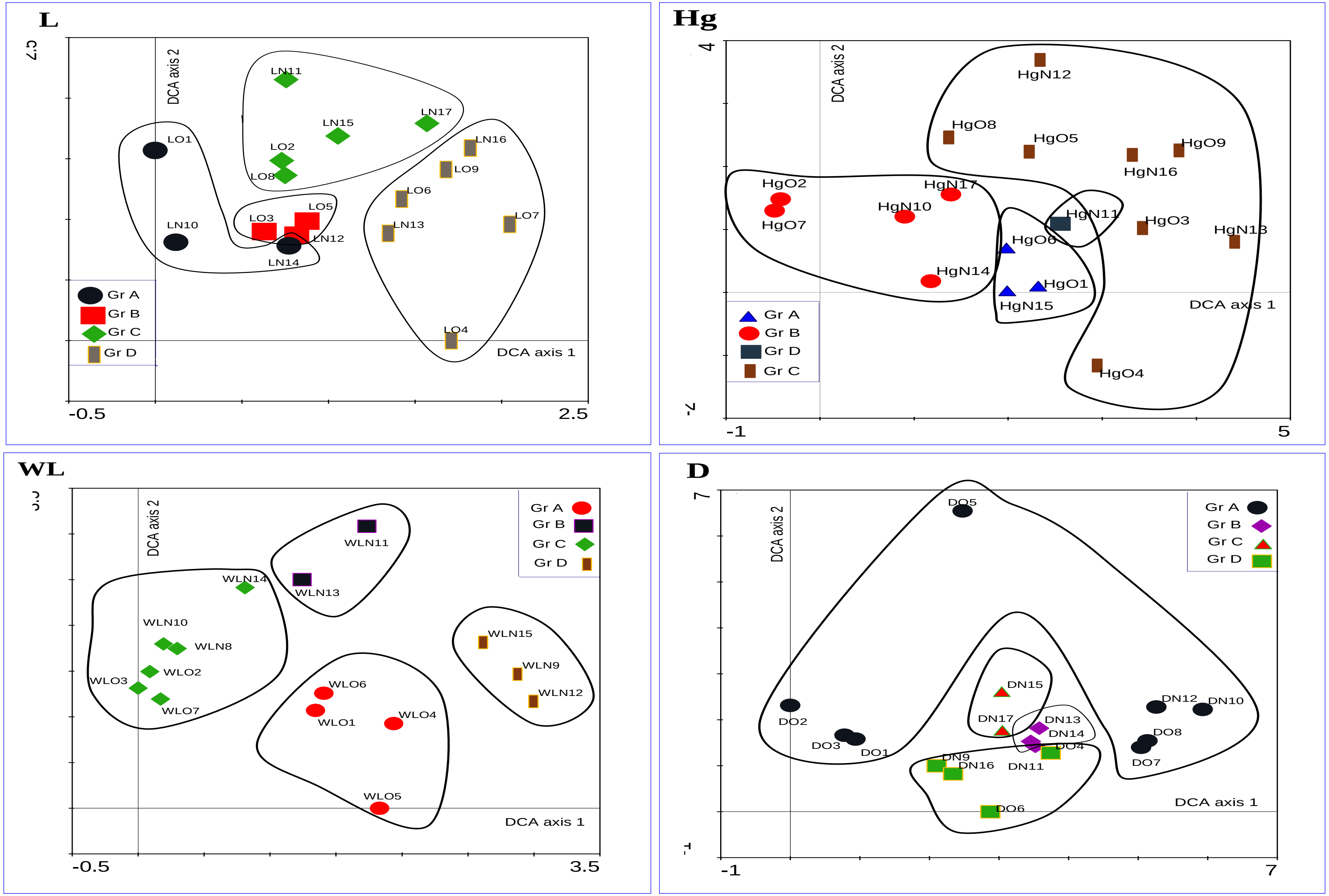

Figure (3): The 16 vegetation groups in the investigated habitats are represented in the ordination diagram of the Detrended Correspondence Analysis. L, Lawn lands; Hg , House gardens; W, Waste grounds and D, Bordering desert.

organic matter, sodium and calcium, whereas negatively with bicarbonates, silt and sand. However, in waste grounds, the CCA axis one (organic matter / chlorides gradient) related positively with organic matter and sand, while negatively with chlorides, calcium, magnesium and sulfates. the second axis (potassium/pH gradient) was positively associated with potassium and sand and negatively with pH, sulfates, organic matter and silt.

In the bordering desert, CCA axis one (clay/sand gradient) related positively with clay and silt; negatively with sand, organic matter, calcium, potassium and sodium. Whereas CCA axis 2 (clay/ Shannon's index gradient) associated positively with clay, pH, sulfates and calcium, and negatively with Shannon's index, species richness, sand and organic matter. The results of Monte Carlo permutation test of the eigenvalue for axis1 were nonsignificant in lawns and house gardens ($p \leq 0.736$ and 0.8, respectively), significant ($p \leq 0.034$) in waste grounds and highly significant ($p \leq 0.008$) in bordering desert, proving that the patterns which were observed were not random

DISCUSSION

The studies on species enrichment in urban areas had provided ample evidence of increased plant diversity in urbanized places compared to the surrounding countryside (Kühn *et al*., 2004). Overall, there were 249 reported species included 189 genera and 64 families, of which 138 cultivated species and 111 native.

In consistent with current findings, the species richness in urbanized areas of lower Egypt (Abd El-Ghani *et al*., 2011a; 2015a; b) was higher than that in the neighboring non-urbanized areas of the Nile Delta region (Abd Al-Azeem, 2003; Abd El-Ghani *et al*., 2011b).

The results demonstrated clear relation among species richness and town/city size, inhabitant's number and industrial area space (shown in Table 1). The more increase the spatial extent of cities/towns, the greater the diversity of plants (Pyšek, 1998; Wittig, 1991). On the contrast, increasing inhabitant's number and industrial areas caused decline in plant biodiversity. This can be explained according to Ali *et al*. (2000) who reported that the urban anthropogenic (traffic and industrial) activities generates a lot of air pollutants which operate as stress factors causing plant toxicity, decreased plant richness and vegetation damage. Furthermore, there is continuous trampling in urban habitats which destroy soil structure and impact on floristic composition causing vegetation cover loss (Frenkel, 1970; Agnew, 1994).

In our study, lawns and house gardens accommodated the highest richness, in contrast to waste grounds that harboured the poorest diversity. Thompson *et al*. (2003) referred to public, house gardens and lawns as

Table (5): Physiochemical properties and plant species diversity of soil collected from different habitats. The measured soil characters include organic matter (OM), soil reaction (pH), electrical conductivity (EC), potassium (K^+), sodium (Na^+), calcium (Ca^{+2}), magnesium (Mg^{+2}), chlorides (Cl^-), bicarbonates (HCO^{3-}), and sulfates (SO_4^{-2}).

Soil Characterization	Investigated area			
	Habitats†			
	L	Hg	W	D
Soil texture (%)				
Sand	0.686	0.199	0.699	0.264
Silt	0.781	0.677	0.897	0.721
Clay	0.586	0.339	0.686	0.645
OM (%)	0.583	0.251	0.01**	0.880
pH	0.867	0.047*	0.359	0.127
EC(dS m^{-1})	0.485	0.591	0.000**	0.542
Soil minerals (meq l^{-1})				
Na^+	0.650	0.681	0.000**	0.548
K^+	0.946	0.228	0.144	0.164
Ca^{+2}	0.454	0.825	0.014*	0.587
Mg^{+2}	0.300	0.842	0.002**	0.622
Cl^-	0.745	0.537	0.000**	0.587
HCO_3^-	0.376	0.269	0.015*	0.328
SO_4^{-2}	0.808	0.104	0.035*	0.693
Species diversity index				
H′	2.830	2.800	2.690	2.630
***p* value**	0.016*	0.187	0.062	0.000**
SR	2.81	2.77	2.67	2.77
***p* value**	0.014*	0.002**	0.033*	0.000**

† L, Lawn lands; Hg, House gardens; W, Waste grounds and D, Bordering desert; H′, Shannon's index; SR, species richness. *, $p \leq 0.05$ and **, $p \leq 0.01$.

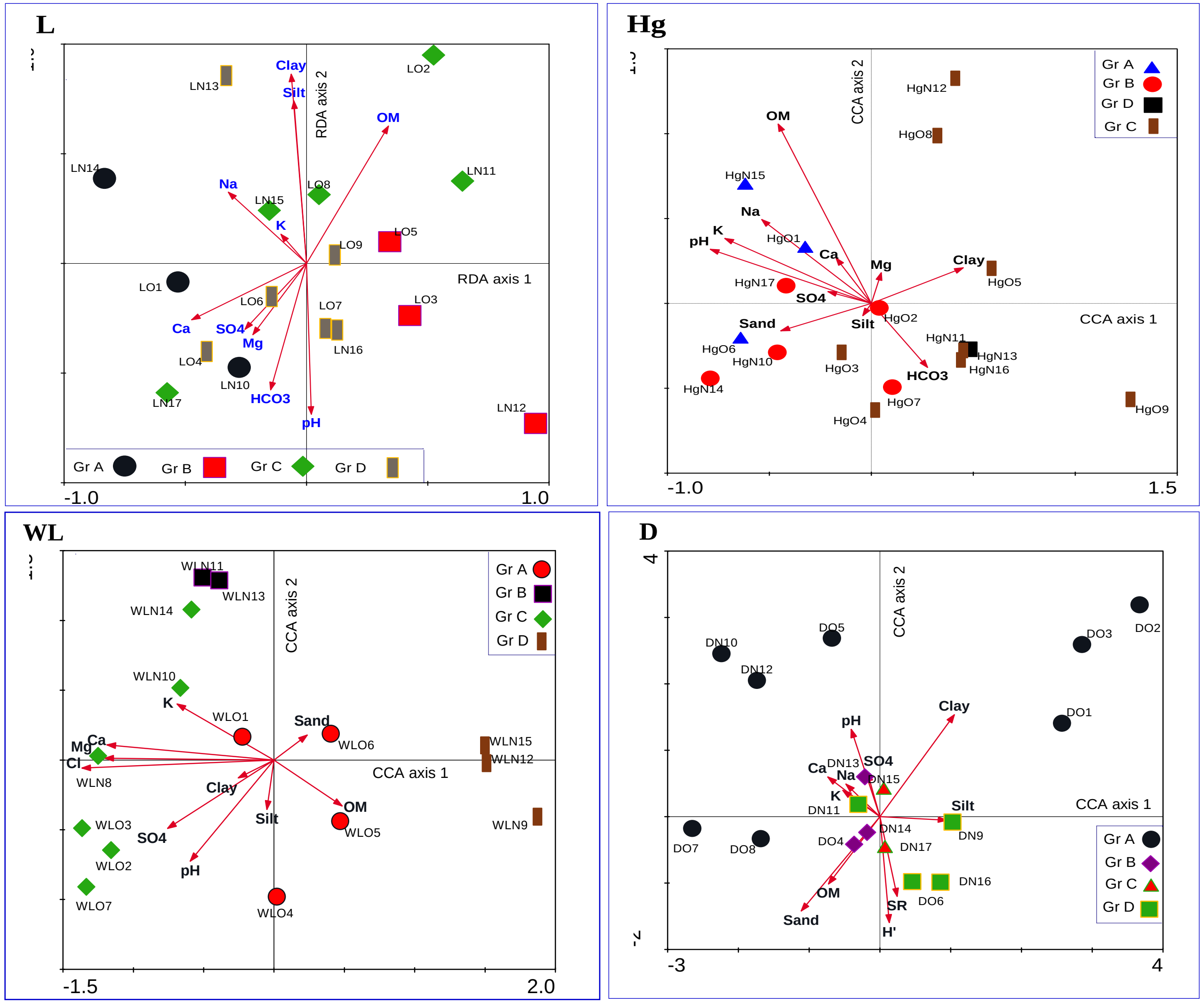

Figure (4): Canonical Correspondence Analysis (CCA) biplots showing the plots distribution in the investigated habitats, with soil factors and their vegetation groups. L, Lawn lands; Hg, House gardens; W, Waste grounds and D, Bordering desert.

Table (6): Inter-Set correlations of soil characterization, species-environment correlations, and eigenvalues in four investigated habitats using CCA Analysis.

Measured parameters	Investigated area Habitats†							
	L		Hg		W		D	
Axes	**Ax_1**	**Ax_2**	**Ax_1**	**Ax_2**	**Ax_1**	**Ax_2**	**Ax_1**	**Ax_2**
Eigenvalues	0.115	0.093	0.266	0.243	0.572	0.315	0.508	0.410
Species-environment correlations	0.972	0.960	0.979	0.989	0.976	0.944	0.992	0.994
Soil characterization								
Soil texture (%)								
Sand	NS	NS	-0.2898	-0.1115	0.1592	0.1247	-0.4297	-0.5592
Silt	-0.0507	0.7114	-0.0270	-0.0503	-0.0339	-0.2459	0.3650	-0.0208
Clay	-0.0607	0.8293	0.2950	0.1450	-0.1716	-0.0889	0.4063	0.6040
OM (%)	0.3285	0.6020	-0.2981	0.7304	0.3271	-0.2287	-0.2806	-0.3985
pH	0.0191	-0.6600	-0.5156	0.2202	-0.4024	-0.5045	-0.1570	0.5168
Soil minerals (meq l^{-1})								
Na^+	-0.3133	0.3121	-0.3512	0.3410	NS	NS	-0.1849	0.1932
K^+	-0.1027	0.1282	-0.4692	0.2647	-0.4656	0.2794	-0.2029	0.1558
Ca^{+2}	-0.4605	-0.2469	-0.1124	0.1851	-0.8016	0.0754	-0.2841	0.2349
Mg^{+2}	-0.2149	-0.3114	0.0317	0.1248	-0.8124	0.0091	NS	NS
Cl^-	NS	NS	NS	NS	-0.9222	-0.0402	NS	NS
HCO_3^-	-0.1440	-0.5536	0.1801	-0.2602	NS	NS	NS	NS
SO_4^{-2}	-0.2466	-0.2882	-0.1393	0.0481	-0.5108	-0.3409	-0.0677	0.2600
Species diversity index								
SR	NS	NS	NS	NS	NS	NS	0.0945	-0.4727
H'	NS	NS	NS	NS	NS	NS	0.0514	-0.6279

†L, Lawn lands; Hg, House gardens; W, Waste grounds and D, Bordering desert ; NS, nonsignificant value.

extremely rich in plant species. Urban forests have been the subject of numerous researches as possible models for systems that are environmentally sustainable (Lamont *et al*., 1999). The results support those obtained by Eichemberg *et al*. (2009) and show higher diversity in urbanized man-made habitats compared to un-urbanized habitats, where they are blessed with a better environment condition and more human-management. Serra *et al*. (2008) and Hussein *et al*. (2021) emphasized the human and natural factors had various influences on plant variation in different habitats.

According to Hamdy (2010) and El-Hady (2011), woody perennials comprise the dominant plant species in urban ecosystems across various regions of Egypt. This can be attributed to their extensive root systems, which allow them to access water stored at different soil depths (Abd El-Ghani and Abd El-Khalik, 2006). Moreover, the growing cultivation of trees is attributed to their dense foliage, wide crowns, substantial stature, and their ability to provide effective shading (Gatrell and Jensen, 2002). While annuals were the less common due to some agricultural activities (e.g. weeding, ploughing and hoeing). In accordance with these reports, the life span composition in the investigated habitats clarified that, perennials constitute majority of listed species in the house gardens (78.3%), lawns (75.1%), bordering desert (54.8%) and nearly 49% in waste grounds habitat.

The recognized habitats can be separated into three essential groups based on Pearson's coefficient of floristic similarity; the first group included house gardens and lawns. The significant positive correlation between these two habitats was expected. This may be due to the fact that they are man-made (cultivated) habitats and more ornamental and artificial of any of the other vegetation in the urbanized regions. On the other hand, waste grounds constituted the second group, and bordering desert (not man-made) habitats represented the third group. Not only the desert habitats showed significant negative correlations with lawns and house gardens, but also it exhibited significant positive correlations with waste grounds. The current data were further confirmed the reports of Abd El-Ghani *et al*. (2010, 2011b).

The sixteen identified vegetation groups in the four habitats under investigation after application of multivariate methods clarified that the most of the dominant species in lawns and house gardens were cultivated plants and weeds of arable lands. These data were agreed with those of earlier research on plant communities in different Egyptian locations e.g. Abd El-Ghani and El-Sawaf (2004) and Turkey (2009). Furthermore, the four identified vegetation groups in the waste grounds habitat were consistent with results recorded by Abd El-Ghani *et al*. (2015b) who recognized five groups for urbanized areas in the desert landscape. Also, Abd El-Ghani *et al*. (2011b) reported 3 vegetation groups in south of Nile Delta. In this context, it can be mentioned that *Phragmites australis, Bassia indica, Launaea nudicaulis, Tamarix nilotica and Pluchea dioscoridis* are relatively dominant species that have been associated with waste grounds. This observation can be explained by the habitat heterogeneity, as the most were halophytic species are believed to be more resistant to salt stress. On the other hand, xerophytic plants formed the framework of the 4 separated groups of the bordering desert. These groups had analogues in southern and northern regions of the Egyptian eastern desert (Abd El-Ghani *et al*., 2013; Salama *et al*., 2013 and 2016).

According to the species distribution of the study area, some species including *Pluchea dioscoridis, Phragmites australis* and *Cynadon dactylon* were recorded in all or most of the habitats. In contrast, because of the adaptations to particular habitats, 42.6% of the total flora exhibited some degree of fidelity, meaning they were only observed in specific habitat and do not recorded in nowhere else. These species were distributed in lawn lands, house gardens, waste grounds and bordering desert in percentage of 23.12%, 16.78%, 20.51% and 54.83%, respectively. Explanation of a specific plants' high ecological amplitude is their highly successful vegetative spread and seed production (Täckholm, 1974). According to Berzaghi *et al*. (2020), who confirmed the previous hypothesis, the thriving of some plants in several environments was associated with their high flexibility in different conditions. These explications were notably supported by the current work, which based on species' traits in the investigated habitats.

The road sides (represent open areas) at the borders of studied cities allow invasive species to colonize and spread widely into the bordering desert regions. Most of introduced species were ruderal and segetal weeds associated with arable lands (e.g. *Zea mays, Brassica tournefortii, Coronopus didymus, Phalaris minor* and *Tamarix nilotica*) inhabit Nile Delta of Egypt (Salama *et al*., 2012). This data support the conclusion of Forman and Alexander (1998). Also in the reverse trend, some desert plants (e.g. *Launaea capitata, Erodium glaucophyllum* and *Tribulus bimucronatus* var. *bispinulosus*) were capable to invade the urbanized zone. Abd El-Ghani *et al*. (2011b; 2015b) indicated similar results in the Nile Delta and some neighboring cities, respectively. Grime (1979) added that high stressed regions are sites with low competition, allowing invasive species to be established.

The present results revealed an association between soil factors and species distribution in the studied habitats presented in the (CCA) biplots. Clearly, each of clay, organic matter, pH, bicarbonates and calcium are highly correlated with weed/cultivated plant groups in lawns and house gardens; while organic matter, potassium, chlorides and pH are highly correlated with helo/halophytic plant groups in waste grounds, and xerophytic plant groups with clay and sand gradient in the bordering desert.

The discharge of organic/inorganic refuses (e.g. garden and factories refuses, buildings debris and rubbish dumps) are may be lead to increase nutrients supplies in the urban habitats of the studied cities. Various plants grown in green landscape were fertilized several times during the growing season with organic matter and nutrient solutions containing many minerals e.g. nitrogen, calcium, phosphorus and potassium where, Calcium carbonate fertilizer is used to reduce acidity by balancing soil pH. Sukopp *et al*. (1979) demonstrated that urban soil is rich in construction remains such as mortar, bricks and cement, which causes an increase in alkalinity. Similar observation was recorded by Godefroid *et al*. (2007) showing effect of soil factors on the floristic structure in urbanized waste lands habitats. The current findings in line with Mohamed *et al*. (2019), who reported that as urbanization reduced from the middle of the Nile delta to its desert edges, the percentage of sandy soil increased while organic matter, silt, nitrogen and phosphorus declined. They added that the soil of desert borders combines with the pure cultivated lands inside the middle of the Nile Delta gradually.

The high vegetation diversity of urban lawns and house gardens is correlated with increased soil fertility. The low species richness of bordering desert and waste grounds, on the other hand, may be attributed to the majority of their flora are highly specialized to those habitats of the harsh conditions (such as salinity and aridity). Zahran and Willis (1992) came to a similar conclusion of the plant vegetation in Egypt's regions that were under salinity and aridity stress.

CONCLUSION

More research is needed to identify the factors influencing species diversity patterns, vegetation structure, and the role of environmental conditions in the urban flora and ecology of new cities in the Egyptian desert landscape. For this reason, this study was undertaken. Like other new desert urbanized areas, most of the floristic composition belonged to six species-rich families (Asteraceae, Poaceae, Fabaceae, Euphorbiaceae, Chenopodiaceae and Brassicaceae) occupied 4 principle habitats: lawn lands, house gardens, waste grounds and bordering desert. Diversity of plant species in the investigated area was low because of the harsh environmental conditions. Spatial patterns of species diversity were most closely related to the heterogeneity of soil. The plant species diversity in the managed urban habitats (lawns and house gardens) were higher than the unmanaged ones (waste grounds and bordering desert). Weeds of cultivation were the dominant in managed habitats, whereas xerophytes and halophytes dominated the unmanaged habitats. Significant negative correlations between the desert habitats with lawns and house gardens were calculated. Gradients in soil texture and nutrients were the key factors determining the vegetation composition in these areas. The vegetation groups and diversity were correlated with edaphic factors that perform a significance role in species distribution. Therefore, we suggest broader management strategies to conserve the biodiversity of urbanized areas.

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استكشاف ديناميكا الغطاء النباتي الخضري وخصائص الموقع في الموائل المدارة بشريا شمال شرق القاهرة، مصر

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الملخــص العــربي

تم تقييم العلاقة بين التركيب الفلوري وخصائص التربة للموائل الممثلة في مدينتين حضريتين جديدتين تم إنشاؤهما في الصحراء الشرقية المصرية وذلك من خلال مسح 66 موقعا وتعيين 13 عاملاً بيئيًا في أربعة موائل رئيسية (الحدائق المنزلية والمروج والأراضي المهملة والصحراء المتاخمة) واقعة داخل المدن باتجاه الضواحي. وقد بلغ إجمالي النباتات المسجلة 249 نوعًا مكونة الفلورة الرئيسية، حيث تضم 138 نباتًا منزرعًا و 63 نوع عشبي و 44 نباتًا جفافياً و 4 انواع من الأشجار والشجيرات البرية. كانت المروج أكثر الموائل تنوعا (173 نوعًا)، تليها الحدائق المنزلية (143 نوعًا)، ثم الصحراء المتاخمة (62 نوعًا) والأراضي المهملة (39 نوعًا). تم تحديد ستة عشر مجموعة نباتية وتسجيل العوامل البيئية التي تتحكم فيها وذلك في الموائل الأربعة محل الدراسة. أنتج تحليل التشابه القويم (CCA) نمطًا مشابهًا لذلك الخاص بتحليل التشابه غير الموجه (DCA)، مما يدل على أن مجموعات الأعشاب/النباتات المزروعة في الموائل التخليقية التي من صنع الإنسان مرتبطة ارتباطًا وثيقًا بالطين ودرجة الحموضة والمواد العضوية ونسبة البيكربونات والكالسيوم ؛ والمجموعات النباتية المحبة للماء/ المحبة للملوحة في الأراضي المهملة ترتبط بدرجة الحموضة والمواد العضوية ونسبة البوتاسيوم والكلوريدات؛ بينما ترتبط النباتات الجفافية في الصحراء المتاخمة بتدرج الطين والرمل.