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Effect of human activities on floristic composition and diversity of desert and urban vegetation in a new urbanized desert ecosystem

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ABSTRACT

Human impact in newly urbanized deserts creates new environments that may favor the establishment/dominance of certain plant species. In this study, we showed how the human activities during desert urbanization do affect distribution, composition and diversity of plant species in a new urban ecosystem. In a field study during 2015–2016 and 2017–2018 growing seasons, we investigated these vegetation criteria in three new habitats created recently due to human manipulations in addition to the old habitat of such area (i.e. the desert). We also compared vegetation criteria comprising the floristic cover, composition and diversity between the desert locations inside and on the outskirts of the city. The detrended correspondence analysis (DCA) successfully separated the different habitats studied. Besides, the floristic composition and diversity were significantly varied amongst these habitats. The canonical correspondence analysis (CCA) revealed an apparent correlation between floristic composition and soil criteria across the study area. For the desert vegetation, the cover values of both *Tamarix nilotica* and *Zygophyllum coccineum*, in addition to the whole diversity indices, were significantly suppressed in the desert fragments inside the newly constructed city in comparison with their cover in the desert adjacent to it. Moreover, the cover of both species was significantly declined in 2018 compared with their cover in 2015. On converse, the covering areas of *Phragmites australis* and *Bassia indica* were increased after intensive constructions in 2018. These results suggest that the human activities and, consequently, urbanization may influence plant life in newly urbanized desert ecosystems, leading to dispersal of new species and destruction of plant cover in some parts of the desert. Efforts and conservation strategies should be devoted to save the desert species that are vulnerable to elimination due to expansion of urbanization.

1. Introduction

In the last decades, urbanization has been induced worldwide with ecological and environmental issues, which led to fundamental changes in land use and landscape pattern around the globe, especially in the developing countries (Su et al., 2012; Weng, 2007). Due to the continuous growth of the human communities in old cities of the arid and semi-arid regions, it was necessary for the governments to overcome the overcrowding problem throughout the expansion of housing programs, road construction, pipeline establishment and intensive motor transport into the deserts. With more human activities and disturbances in the urbanized areas in the deserts, damage of natural vegetation has become inevitable and the wild plants have been removed from considerable areas. Therefore, it was important to assess the human impact as a most legitimate ecological factor and a first cause of change in this new habitat (Alberti, 2008). The effects of human activities on the desert vegetation have been reported in parts of the arid region of the world (Batanouny, 1983, 1999; Abd El-Ghani et al., 2017). Additionally, a few floristic studies in some anthropogenic habitats due to urbanization of desert have been investigated in Egypt (Abd El-Ghani et al., 2011, 2012, 2015). However, these studies may be insufficient work as new cities in the desert are being built, or under construction, with the creation of new socioeconomic activities, climate, soil conditions and water availability, leading to the appearance of certain plant cover with new composition and diversity which are still unknown. It was therefore necessary to fill this gap.

Urban green areas represent one of the essential components of newly urbanized desert sectors that draw residents to inhabit these new cities/towns. A field of particular interest to urban ecology is the study of green areas of the new cities in relation to urbanization which has influenced vegetation all over the world (McKinney, 2002; Pennington et al., 2010; Abd El-Ghani et al., 2011). Urbanization directly impacts not only the

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entire ecosystem through the replacement of vegetation with urban infrastructures such as buildings, roads, gardens and parks, but also alters floristic composition, diversity and distribution through fragmentation and degradation processes (e.g., the land and water use) which increase the habitat efficacy for immigration of so many plant species. In this study, we will show the man's effect, with respect to urbanization being processed in a newly urbanized desert region, on plant cover, floristic composition and diversity of plants detected amongst some anthropogenic habitats compared to the unaffected desert.

In desert ecosystems, where available water is scarce, human activities, associated with more land-water use, create new environments which favor distribution and cover of very different plant species. Land and water use and, consequently, water availability in the environment near human settlements are likely altered due to irrigation, wastewater discharge, and construction of gardens and parks as new approaches for urbanization (Roach et al., 2008). One of the prominent problems in the badly-designed newly urbanized deserts, particularly those of the developing countries, is the improper use of water due to the uncontrolled spilling of water during construction of new buildings. In addition, the overflow of the wastewater from the underground basins is continuously occurring phenomenon in several areas in the new cities, thus modifying the quantity of available water, the rate of water flow, discharge, percolation into groundwater pool, and the frequency and intensity of disturbance events (Paul and Meyer, 2001; Townsend-Small et al., 2013). Consequently, new habitats are likely formed and markedly observed than before. On the other hand, the terrestrial habitat of new urban ecosystems was mainly desert, but due to urbanization and greening purpose, clayey and silty soils were derived from old agricultural systems and introduced into this territory to be more suitable for plantations of gardens and parks, leading to significant changes in the physicochemical characteristics of the soil such as soil texture, pH, electrical conductivity (EC), $CaCO_3$ and organic matter status. These parameters were reported to be controlling composition, diversity and distribution of plant species in different habitats including the old crop farm lands, reclaimed lands, deserts in addition to the new urban areas (Abd El-Ghani et al., 2015; Gomaa et al., 2012; Hegazy et al., 2004). These changes in land use and water availability due to the human activities can favor native plant communities, as well as affect microclimate (Miltner et al., 2004; Paul and Meyer, 2001), and also facilitate the distribution of plants (Daehler, 2003; Song et al., 2017). Therefore, water availability and new soil conditions may become factors sustaining some plants in urban environments. But, what favors what? Which of the anthropogenic habitats formed may facilitate distribution of a certain species within the new area? In this investigation, we will highlight how the system type due to land and water use, either advertently or inadvertently, does influence composition and diversity of plant species in a new urban ecosystem. This will reflect the selectivity of a given species to dominate a given habitat conditions throughout land-water use.

The common reed, *Phragmites australis* Cav. (Trin.) ex. Steud, is a common cosmopolitan weed species that is most commonly found along water-courses, in some areas of cultivation and on sandy sites with occasionally high water table (Boulos, 2005). In newly urbanized-desert cities, the dense patches of such species may appear due to inappropriate water use. These sites may represent a social problem, as they may act as hiding sites for thieves, rodents, stray animals or some harmful insects, particularly near the housing buildings, restaurants and governmental institutions. Therefore, it was necessary to accentuate the spread of such species with urbanization of deserts.

In the light of the above-mentioned statements, two main hypotheses will be tested. (1) Distribution, cover, composition and diversity of the recorded plants vary amongst different anthropogenic microhabitats within an urbanized desert. According to such hypothesis, the main factor controlling these parameters is the land and water use. This hypothesis can be tested throughout comparing floristic composition, cover and diversity among the newly observed habitats in addition to the old one, i.e. the desert, using an adequate ordination analysis (DCA). The soils modified along the study area due to the human settlements will exert a substantial effect on the floristic distribution, composition and diversity. In order to establish the relationship between the considerably altered soil characteristics and the floristic composition, the Canonical Correspondence Analysis (CCA) will be a useful tool. (2) As urbanization was progressed over years, the cover of the desert species is already reduced and, due to the continuous use and release of more water, common water-associated plants such as the common reed will be heavily found than before. This hypothesis can be assayed via measuring the cover of the desert species found and the common reed prior to- and after the human disturbances. Measurements would be possible in desert sites facing the urban crawling, i.e. around and nearby the newly constructed buildings. The main objective of this study is to ecologically evaluate the effects human activities on cover, composition and diversity of plant species in a newly urbanized desert region.

2. Materials and methods

2.1. Study area

The study area, New Beni-Suef city, is one of the common new cities established in the eastern desert of Egypt. It has been fully constructed since 1990 and occupies about 102 km^2. It is located about 124 km south of Cairo on the eastern bank of the River Nile between latitudes 29° 00.90′ to 29° 03.14′ N and longitudes 31° 04.31′ to 31° 08.10′ E, with an elevation of ≈31–58 m a. s. l. (Fig. 1). This city now is abundant in green areas, and several weed species recorded in the agro-ecosystems could dominate this region. Irrigation of the gardens and parks in this city is mainly by sprinklers. Unfortunately, the workers/constructors use water during building the infrastructures carelessly, leading to uncontrolled spilling of water. Furthermore, overflow of wastewater from sewers is a continuous undesirable phenomenon is some places. Thus, four main microhabitats are now recognizable in such new city. The first is the 'desert' (signed as D) which is a natural habitat, receiving water as rainfall, and completely away from human impact. This habitat is located on the outskirts of the study area as well as on points inside the city that are not affected by human activities, and thus this habitat may be set as control. The second represented the sites affected by waters (signed as W); i.e. waters released from large taps at the end of pipelines, used for building infrastructures during urbanization process. After the infrastructure was established, the water pool in these shallow depressions gets dried. The third habitat was that affected by the wastewater; i.e. due to rash of sewage continuously, (signed as WW). The final one is the gardens and parks (signed as G), where the environments are well-elaborated by humans due to soil transported and standard application of water for irrigation. The different habitats selected with their characteristic vegetation are well-represented in Fig. 2.

These new environments, due to water released, may facilitate germination and establishment of many plant species already dispersed. Thus, in addition to gardens and parks designed, we will explore which species favored amongst these new habitats. With respect to climatic conditions, this area is located in a semi-arid belt, with a slightly rainy temperate winter and a dry hot summer (Hassan, 2018).

2.2. Field study

A total of 100 plots (10 m length × 1 m width, giving 10 m^2 each) were randomly sampled from the vegetation representing four different habitats. The study was conducted during 2015–2016 and 2017–2018 growing seasons. Twenty plots were selected in each of desert, watery and the wastewater-affected habitats and forty ones were chosen in the gardens and parks. Sample size was chosen according to the approximate proportion of each habitat type in the study area. In each plot, three vegetation criteria were recorded: (1) species richness (S), i.e. the total number of plant species observed; (2) plant cover of each species in addition to the total plant cover of all species. The cover was measured

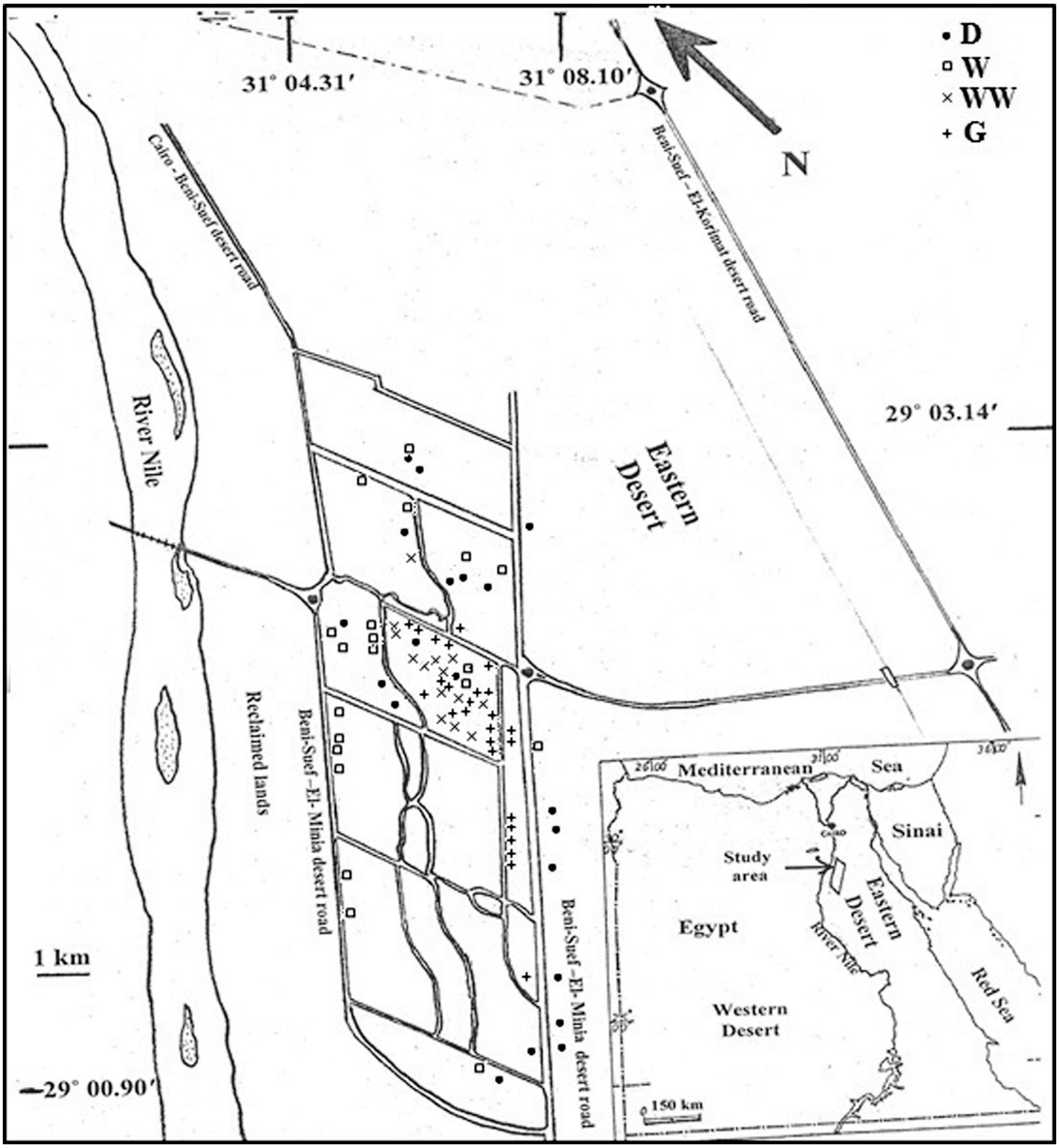

Fig. 1. The map of the study area showing its structure, location, coordinates and sampling locations of the different habitats.

visually as the area occupied by each species. The relative cover of each species (expressed as %) was calculated using the equation: relative cover = [cover of a species i/cover of all species] × 100. (3) Three diversity indices; Shannon-Weaver index (H′), Evenness index (E) and Simpson's index for diversity (D), were used to measure the floristic diversity in each habitat (Pielou, 1975; Zhang, 1995) as follows:

$$H'^{s}_{i=1} = -\sum (pi \times \ln \ pi)$$

$$E'^{s}_{i=1} = \left[-\sum (pi \times \ln \ pi)\right] \Big/ \ln \ S$$

$$D^{s}_{i=1} = \frac{1}{\sum pi^2}$$

where S is the species richness in each plot and pi is the relative cover of the species i. Species identification and nomenclature followed Boulos (1999, 2000, 2002, 2005). These diversity indices were commonly used in ecological applications (Hassan, 2018).

In order to ecologically evaluate the human activities on the desert vegetation, two steps were followed. The first was to measure the floristic composition, cover and the above-mentioned diversity indices for the desert vegetation in desert locations on the outskirts of the new city; i.e. just adjacent to the city, and in desert fragments inside the city. These desert points may be subjected to minor human disturbances such as overcutting for plants. But, they may be left without urbanization and remained as desert. A total of twenty plots were selected randomly in each case as mentioned above.

In the past few years, vast areas were subjected to intensive human activities. As a result, more human impact on vegetation was predicted. In this study, we had to compare the cover of some plant species in the impacted sites before and after human disturbances. Thus, we compared the cover of some affected species in 2015 (before human impact) and in 2018 (after human impact). Other twenty plots were selected randomly also in each case, i.e. either before or after human activities, in the desert sites facing the new constructions. Three years may be short time for potential evaluation. However, the effects of intensive constructions and

Fig. 2. Representative photos for the different habitats in the study area. The names of the habitats were abbreviated as D: desert, W: watery sites, WW: wastewater-affected sites and G: gardens and parks.

settlements on vegetation in very different areas were enough to be considered. The average meteorological data of the study area in both years were summarized in Table 1.

2.3. *Soil analysis*

From each plot, three soil samples were collected from 0–30 cm depth and pooled together forming one composite sample. These samples were

Table 1
Mean average meteorological data of the study area in 2015 and 2018.

Parameter	Year	Jan.	Feb.	Mar.	Apr.	May	Jun	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Average maximum temperature (°C)	2015	24	22	28	31	36	37	40	41	40	31	25	20
	2018	19	26	28	29	34	35	35	35	34	30	26	21
Average minimum temperature (°C)	2015	14	13	19	22	25	28	30	32	30	21	16	11
	2018	12	14	16	18	22	24	24	26	25	21	17	13
Rainfall (mm m^{-2})	2015	2	610	14.5	1	0	0	0	0	0	1	3	917
	2018	13	22	604	11	0	0	0	0	0	0	4	750
Relative Humidity (%)	2015	61	54	49	42	39	36	40	44	48	54	58	63
	2018	55	61	31	44	34	36	39	40	46	45	45	60
Wind speed (km hr^{-1})	2015	11.2	11.5	14.0	15.1	15.5	16.2	15.5	17.0	14.8	14.0	12.2	11.9
	2018	13.3	12.2	14.8	16.9	20.2	19.4	19.4	20.2	19.8	16.9	10.1	12.9

air dried, sieved through 2 mm sieve and stored in paper bags until analysis. The soils were analyzed for determination of soil texture, pH, electrical conductivity (EC), in addition to soil $CaCO_3$ and the organic carbon (OC). These soil criteria are important to be determined as they affect distribution and composition of flora of a given area (Hegazy et al., 2004; Gomaa, 2012a; Abd El-Ghani et al., 2015).

For determination of soil texture, the percentages of sand, silt and clay in the inorganic fraction of soil were measured using the hydrometer method (Bouyoucos, 1962). Both pH and EC were measured in soil-water extract using deionized water. Soil pH was measured in the soil extract (1:2.5 w/v) with a digital pH meter (AD 3000), while EC was measured in another soil extract (1:5 w/v) using a conductivity meter (Jenway 3305). The percentage of soil $CaCO_3$ was estimated using the titration method according to Jackson (1967). Oxidizable organic carbon and organic matter were measured using Walkley and Black's method (Walkley and Black, 1934).

2.4. Statistical analyses

The detrended correspondence analysis (DCA) was applied in order to

Table 2
A list of the species recorded in the study area with their families, life forms, life span and mean relative cover (%) in the four habitats abbreviated as D: desert, W: water-affected sites; WW: wastewater-affected sites, G: gardens and parks. The life forms were abbreviated as Th: therophytes, H: hemicryptophytes, Ge: geophytes, Ch: chamaephytes, Ph: phanerophytes, and life span were Ann.: annual and Per.: perennial. –: not detected.

Species	Family	Microhabitat				Life form (life span)
		D	W	WW	G	
Alhagi graecorum Boiss.	Fabaceae	3.30 b	– a	– a	– a	H (Per.)[††]
Amaranthus viridis (Linn.)	Amaranthaceae	– a	– a	31.00 c	0.30 b	Th (Ann.)[††]
Anagallis arvensis L.	Primulaceae	–	–	–	0.12	Th (Ann.)[†]
Apium leptophyllum (Pers.) F. Muell. ExBenth.	Apiaceae	– a	– a	– a	4.70 b	Th (Ann.)[††]
Aster squamatus (Spreng.) Hieron.	Asteraceae	–	–	–	0.90	Th (Ann.)[†]
Avena fatua L.	Poaceae	–	–	–	0.81	Th (Ann.)[†]
Bassia indica (Wight) A.J.Scott	Chenopodiaceae	21.72 b	– a	– a	– a	Th (Ann.)[††]
Bidens pilosa L.	Asteraceae	–	–	–	0.28	Th (Ann.)[†]
Bromus catharticus Vahl	Poaceae	–	–	–	0.75	Th (Ann.)[†]
Cenchrus echinatus L.	Poaceae	– a	– a	2.60 b	10.07 c	Th (Ann.)[††]
Chenopodium murale L.	Chenopodiaceae	– ab	– ab	0.90 b	– a	Th (Ann.)[††]
Citrullus lanatus (Thunb.) Matsum. & Nakai	Cucurbitaceae	– a	– a	1.24 b	– a	Th (Ann.)[††]
Corchorus olitorius L.	Tiliaceae	–	–	–	0.93	Th (Ann.)[†]
Coronopus didymus (L.) Sm.	Brassicaceae	– ab	– ab	3.50 b	– a	Th (Ann.)[††]
Cucumis melo L.	Cucurbitaceae	– ab	– ab	1.0 b	– a	Th (Ann.)[††]
Cynanchum acutum L.	Asclepiadaceae	–	0.30	–	–	Ch (Per.)[†]
Cynodon dactylon (L.) Pers	Poaceae	– a	11.5 ab	20.00 b	22.40 a	Ge (Per.)[††]
Cyperus laevigatus L.	Cyperaceae	– a	– a	5.50 b	– a	Ge (Per.)[††]
Dactyloctenium aegyptium (L.) Willd.	Poaceae	–	–	–	0.8	Th (Ann.)[†]
Dichanthium annulatum (Forssk.) Stapf	Poaceae	–	–	–	1.90	H (Per.)[†]
Digitaria sanguinalis (L.) Scop.	Poaceae	–	–	–	2.15	Th (Ann.)[†]
Echinochloa colona (L.) Link.	Poaceae	– a	– a	1.39 c	0.09 b	Th (Ann.)[††]
Echinochloa crus-galli (L.) P. Beauv	Poaceae	–	–	0.60	–	Th (Ann.)[†]
Eragrostis pilosa	Poaceae	– a	– a	– a	16.02 b	Th (Ann.)[††]
Euphorbia hirta L.	Euphorbiaceae	–	–	–	0.40	Th (Ann.)[†]
Euphorbia peplus L.	Euphorbiaceae	–	–	–	2.16	Th (Ann.)[†]
Euphorbia prostrata L.	Euphorbiaceae	–	–	–	2.65	Th (Ann.)[†]
Imperata cylindrica (L.) Raeusch	Poaceae	–	–	–	0.38	H (Per.)[†]
Lactuca serriola L.	Asteraceae	–	–	–	0.20	Th (Ann.)[†]
Lolium temulentum	Poaceae	–	–	–	2.07	Th (Ann.)[†]
Lycopersicon esculentum	Solanaceae	– a	– a	1.90 b	– a	Th (Ann.)[††]
Malva parviflora L.	Malvaceae	–	–	–	0.57	Th (Ann.)[†]
Medicago lupulina L.	Fabaceae	–	–	–	3.0	Th (Ann.)[†]
Medicago polymorpha L.	Fabaceae	– a	– a	– a	4.05 b	Th (Ann.)[†]
Melilotus indicus (L.) All.	Fabaceae	– ab	– ab	– a	1.70 b	Th (Ann.)[††]
Oxalis corniculata L.	Oxalidaceae	–	–	–	2.46	H (Per.)[†]
Paspalum dilatatum Poir.	Poaceae	–	–	–	7.90	H (Per.)[†]
Phragmites australis (Cav.) Trin.ex Steud.	Poaceae	– a	85.2 c	11.00 b	– a	Ge (Per.)[††]
Plantag major L.	Plantaginaceae	– ab	– ab	– a	3.50 b	Th (Per.)[††]
Plantago amplexicaulis Cav.	Plantaginaceae	–	–	–	0.40	Th (Ann.)[†]
Plantago lanceolata L.	Plantaginaceae	–	–	–	0.11	Th (Ann.)[†]
Pluchea dioscoridis (L.) DC.	Asteraceae	– a	– a	0.21 b	– a	Ph (Per.)[††]
Poa annua L.	Poaceae	–	–	–	0.08	Th (Ann.)[†]
Polypogon monspeliensis (L.) Desf.	Poaceae	– a	– a	3.20 b	– a	Th (Ann.)[††]
Polypogon viridis (Gouan) Breistr.	Poaceae	–	–	0.20	–	Th (Ann.)[†]
Portulaca oleracea L.	Portulacaceae	– a	– a	6.90 b	– a	Th (Ann.)[††]
Rumex dentatus L.	Polygonaceae	–	–	0.20	–	Th (Ann.)[†]
Setaria viridis (L.) P.Beauv.	Poaceae	–	–	–	0.12	Th (Ann.)[†]
Sonchus oleraceus L.	Asteraceae	– a	– a	9.20 b	– a	Th (Ann.)[††]
Tamarix nilotica (Ehrenb.) Bunge.	Tamaricaceae	40.10 b	– a	– a	– a	Ph (Per.)[††]
Trifolium resupinatum L.	Fabaceae	– a	– a	– a	6.18 b	Th (Ann.)[††]
Typha domingensis Pers.	Typhaceae	–	3.0	–	–	Ge (Per.)[†]
Zygophyllum coccineum L.	Zygophyllaceae	34.92 b	– a	– a	– a	Ch (Per.)[††]

[†] Non-significant result amongst the different habitats according to Kruskal-Wallis H test.

[††] For the significant results due to Kruskal-Wallis H test, the relative cover values sharing the different letters are significantly different among the habitats according to Dunn's test.

ordinate the stands in two-dimensional space using the relative cover values of the species detected (Hill, 1979). Normality and homogeneity of all results were assessed using the Kolmogorov–Smirnov and Levene's tests, respectively. The data obtained from the different plant communities (cover of the different species, total cover and diversity indices) and soil criteria of the vegetation groups identified by DCA were compared using one-way ANOVA when the results are normal. When the ANOVA showed significant differences, we used the results of the Tukey's test for multiple comparisons of means. If the data presented abnormality and heterogeneity, the nonparametric statistical analysis was applied using Kruskal-Wallis H test. When this analysis revealed significant differences, the Dunn's test was performed for the nonparametric pairwise multiple comparisons of means (Dinno, 2015). Canonical correspondence analysis (CCA) was used to potentially establish the relationship of the floristic composition of the different habitats surveyed with the measured edaphic criteria (Ter Braak, 1986). To assess the human impact on the desert vegetation, the independent-samples T test was applied to find out the potential difference between desert vegetation both inside and just outside the city if the data are normal, and the Mann-Whitney U test was used when these results were abnormal. In addition, the effect of human disturbance was assessed on some species before and after human settlements, particularly in the desert sites (D) around the new constructions, the data were compared using the Paired-Samples T test for normal results. When these data were not normally distributed, the non-parametric Wilcoxon's signed rank test was applied. The data obtained in this study were analysed using the SPSS Statistics software package, version 20.0 (IBM Corporation, USA) at $P < 0.05$ and $P < 0.01$ as probability levels.

3. Results

3.1. Floristic composition

A total of 53 plant species belonging to 46 genera and 22 families were recorded in the study area (Table 2). The largest family was Poaceae (18 species), followed by Fabaceae and Asteraces (5 species for each), Euphorbiaceae and Plantaginaceae (3 species for each), Chenopodiaceae and Cucurbitaceae (2 species for each), and a single species was observed for each of the remaining families. The life form spectrum also exhibited a wide range of variation (Table 2). Therophytes were the predominant life form, constituting about 75.5% of the total flora, followed by hemicryptophytes (9.4%), geophytes (7.5%), chamaephytes and phanerophytes (3.8% for each). The majority of the species detected was annuals (39 species, 73.6%), while the remaining species were perennials (14 species, 26.4%) (Table 2).

3.2. DCA ordination

The application of DCA technique on the cover values of the recorded species in the 100 stands lead to clear separation of four vegetation groups on the ordination planes. The vegetation groups were clearly distinguished and distributed mainly along axis 1 from right to left in the order: D, W, WW and G (Fig. 3). This is confirmed by the analysis of sample scores of DCA axes which revealed that the scores of axis 1 varied significantly ($P < 0.05$) between the habitats studied (Table 3). On the contrary, the scores of DCA axis 2 were not significantly different among the habitats studied. Each vegetation group comprised a set of stands which are similar in their natural vegetation. The eigenvalues for the first two DCA axes (axis 1 and 2) were 0.84 and 0.69, respectively.

3.3. Variation of vegetation and soil among habitats

In general, both vegetation characteristics and soil variables were significantly varied amongst the habitats selected with respect to species composition (Table 2), plant cover, diversity indices and soil conditions (Table 3).

In the desert (D), only 4 species were observed, amongst which *Tamarix nilotica* was dominant and *Zygophyllum coccineum* was co-dominant. The invasive *Bassia indica* was commonly found, whereas *Alhagi graecorum* was recorded as rare in this habitat. Interestingly, their cover values were significantly different ($P < 0.01$) from the new habitats formed (Table 2).

In the newly habitat affected by water release from pipelines (W), *Phragmites australis* was the most prominent species, with relative cover 85.2%. In addition, *Cynodon dactylon* was also commonly associated. The cover of the former was significantly higher ($P < 0.01$) if compared with the remaining habitats. Besides, the later attained higher density in WW and G if compared with its cover in the desert. On converse, *Cynanchum acutum* and *Typha domingensis* were so rare. Meanwhile, they are not affected amongst the habitats studied (Table 2).

In the wastewater-affected sites (WW), *Amaranthus viridis* was dominant (31%), followed by *Cynodon dactylon* (20%) amongst the detected species. Besides, *Phragmites australis*, *Sonchus oleraceus*, *Portulaca oleracea*, *Cyperus laevigatus*, *Polypogon monspeliensis* and *Echinochloa colona* were commonly detected, and their cover values were significantly varied ($P < 0.01$) from the other environments studied. Remarkably, three common cultivated crops; *Citrullus lanatus*, *Cucumis melo* and *Lycopersicon esculentum,* were observed in this habitat. Both *Citrullus* and *Lycopersicon* were of higher cover values ($P < 0.01$) in WW on comparison with the remaining habitats.

In gardens and parks (G), vast plant species were found. Amongst

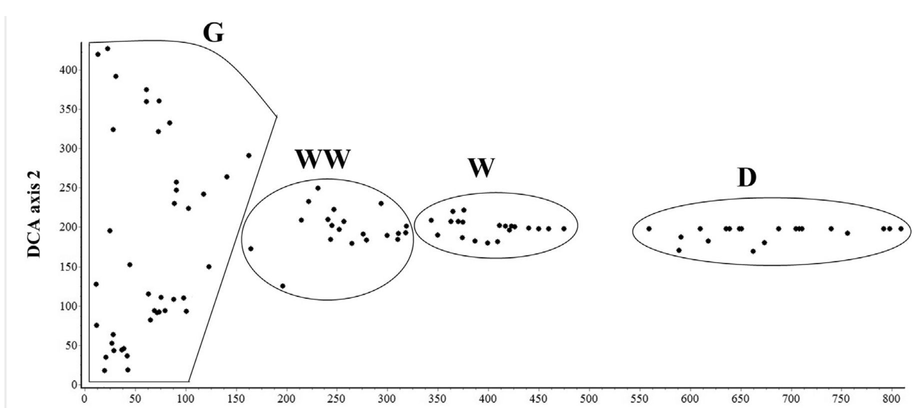

Fig. 3. DCA ordination of the 100 stands based on the mean relative cover values (%) of the species with the vegetation groups. The capital letters indicate the habitats surveyed; D = desert, W = watery sites, WW = wastewater-affected sites, and G = gardens and parks. n = 20 for each of D, W and WW, and n = 40 for G.

Table 3
Plant cover (%), diversity indices and measured soil criteria (mean ± SE) of the different habitats studied. D: desert, W: water-affected sites, WW: wastewater-affected sites, G: gardens and parks.

Parameter	Habitats			
	D	W	WW	G
Plant cover (%)	52.31a ±4.13	67.41b ± 3.18	75.56c ± 2.90	95.94d ± 0.67
Species richness	1.50a ±0.15	1.65a ±0.15	4.20b ± 0.25	4.24b ± 0.19
Shannon-Weaver index	0.26a ±0.08	0.29a ±0.06	1.04b ± 0.07	1.12b ± 0.05
Evenness index	0.35a ±0.10	0.37a ±0.09	0.75b ± 0.03	0.76b ± 0.03
Simpson index	1.33a ±0.11	1.27a ±0.08	2.59b ± 0.19	2.81b ± 0.13
Sand (%)	70.51c ± 0.70	66.26b ± 0.99	67.08b ± 0.97	47.95a ±0.83
Silt (%)	14.51a ±1.12	13.81a ±1.13	11.88a ±0.82	33.70b ± 0.71
Clay (%)	14.98a ±0.86	19.93bc ± 0.89	21.04c ± 0.60	18.36b ± 0.47
pH	8.25a ±0.06	8.17a ±0.07	7.95b ± 0.05	8.00b ± 0.02
EC (μS cm^{-1})	4130.75c ± 832.42	6141.73d ± 878.40	2158.37b ± 244.16	450.74a ±79.95
$CaCO_3$ (%)	3.74c ± 0.23	3.34c ± 0.15	2.90b ± 0.20	2.40a ±0.06
Organic carbon (%)	0.33a ±0.04	0.49a ±0.05	0.86b ± 0.09	1.94c ± 0.04
Score of DCA axis 1	664.50c ± 15.73	417.18b ± 12.06	262.83b ± 7.32	65.43a ±6.48
Score of DCA axis 2	185.30a ±3.34	193.34a ±6.45	211.96a ±5.90	173.40a ±16.98

Values in a row sharing the same letter are not significantly different at the $P <$ 0.05 level.

them, *Cynodon dactylon* was dominant (22.4%), followed by *Eragrostis pilosa* (16%). Very common species were recorded in the areas representing this habitat such as *Cenchrus echinatus* and *Trifolium resupinatum* which were of higher densities if compared with their cover in the rest of the different habitats (Table 2). May be some common species such as *Apium leptophyllum* and *Medicago polymorpha* were detected. However, their cover was just higher from their existence in WW only. The remaining species may be less common or even rare (Table 2).

As shown in Table 3, vegetation cover and species diversity varied amongst the different habitats selected. The total plant cover varied significantly ($P < 0.05$) from the lowest value (52.3%) in desert to the highest (95.9%) in gardens and parks. The measured diversity indices including species richness, Shannon-Weaver, evenness and Simpson indices were significantly ($P < 0.01$) higher in the wastewater-affected sites and gardens.

With respect to soil characteristics, the soils of the desert areas showed significantly higher values of sand and lower values of clay contents in comparison with the anthropogenic habitats (Table 3). The wastewater-affected sites attained higher clay content ($P < 0.01$). Amongst the habitats surveyed, gardens and parks (G) had the lowest content of sand and the highest content of silt ($P < 0.01$). The wastewater-affected sites as well as gardens and parks manifested significantly ($P < 0.01$) lower pH values. The soils in gardens and parks were of lower electrical conductivity, while the opposite was true for those of watery sites (W) ($P < 0.01$). The soils of desert (D) and watery (W) microsites were abundant in $CaCO_3$, while poor in organic matter (Table 3). The contrary was correct for those of gardens and parks, being of lower $CaCO_3$ and higher organic matter contents ($P < 0.01$).

As indicated in Table 3, the DCA axis 1 showed significantly negative correlation ($P < 0.01$) with the plant cover as well as the measured diversity indices.

3.4. Vegetation-soil relationship

The CCA ordination between the floristic composition and the measured soil parameters manifested clear correlation between the habitats surveyed and the soil criteria measured (Fig. 4). Apparently, the floristic composition of gardens and parks (G) was closely associated with soils rich in silt and organic carbon. On converse, the plant species found in the watery (W) and wastewater-affected habitats (WW) were correlated with clay soils. In addition, the species abundant in water-released sites (W), as represented by *Phragmites australis* (of cover 85.2 %), were correlated with soil sand and electrical conductivity (EC). The desert species (D) also displayed a close correlation with soil $CaCO_3$, EC and sand. The eigenvalues of axis 1 and 2 were 0.67 and 0.40, respectively.

3.5. Effect of human activities on desert vegetation

The floristic composition, diversity and soil parameters for the desert vegetation found inside and outside the new city are compared in Table 4. The results showed that the cover value of *Alhagi graecorum* was significantly (P ˂ 0.05) higher inside the city, whereas *Zygphyllum coccineum* was completely absent. In addition, the cavering area of *Tamarix nilotica* was significantly (P ˂ 0.01) suppressed in the inside-desert points left in the city. With respect to floristic diversity, the measured diversity indices for the desert vegetation observed inside the city were significantly (P ˂ 0.05) lower when compared with those measured on the outskirts of this city. Interestingly, the measured soil characteristics were similar in both desert locations.

The covering area of some species under study namely: *Bassia indica*, *Phragmites australis*, *Tamarix nilotica* and *Zygophyllum coccineum*, varied in 2018 in comparison with their cover in 2015. For the desert species, the cover of *Tamarix nilotica* and *Zygophyllum coccineum* was significantly decreased (P ˂ 0.01) (Fig. 5). On the contrary, the cover of *Bassia indica* and *Phragmites australis* was significantly induced in 2018.

4. Discussion

The plant communities in the study area comprised 53 plant species, including 39 annuals (73.6%) and 14 perennials (26.4%). They are also mostly therophytes; i. e. persisting as seeds. The higher contribution of annuals can be related to their short life cycles, absence of the competing crops and the different control strategies that enable them to exhibit better performance if compared to their life in the agro-ecosystem. Besides, they generally have high allocation of resources to the reproductive

Table 4
Plant cover (% of the plot set), diversity indices and measured soil criteria (mean ± SE) of the different desert location inside and just outside the city.

Parameter	Outside the city	Inside the city
Species detected		
Alhagi graecorum	2.60 ± 0.90	10.00* ± 1.43
Bassia indica	20.00 ± 2.73	47.00 ± 12.8
Tamarix noltica	59.00 ± 9.27	5.40** ± 2.25
Zygophyllum coccineum	30.00 ± 7.59	0.0** ± 0.0
Diversity indices		
Species richness	1.70 ± 0.20	1.00* ± 0.24
Shannon index	0.31 ± 0.12	0.00* ± 0.0
Evenness	0.39 ± 0.13	0.00* ± 0.0
Simpson index	1.38 ± 0.19	1.00* ± 0.0
Soil criteria		
Sand (%)	70.20 ± 0.80	72.00 ± 1.15
Silt (%)	14.73 ± 1.33	15.21 ± 0.41
Clay (%)	15.07 ± 0.95	12.79 ± 0.77
pH	8.29 ± 0.04	8.38 ± 0.10
EC	4285.27 ± 983.36	3903.33 ± 589.10
$CaCO_3$ (%)	3.76 ± 0.28	3.28 ± 0.32
OC (%)	0.35 ± 0.04	0.22 ± 0.04

* Significant results from the values measured outside the city at $P < 0.05$.
** Significant results from the values measured outside the city at $P < 0.01$.

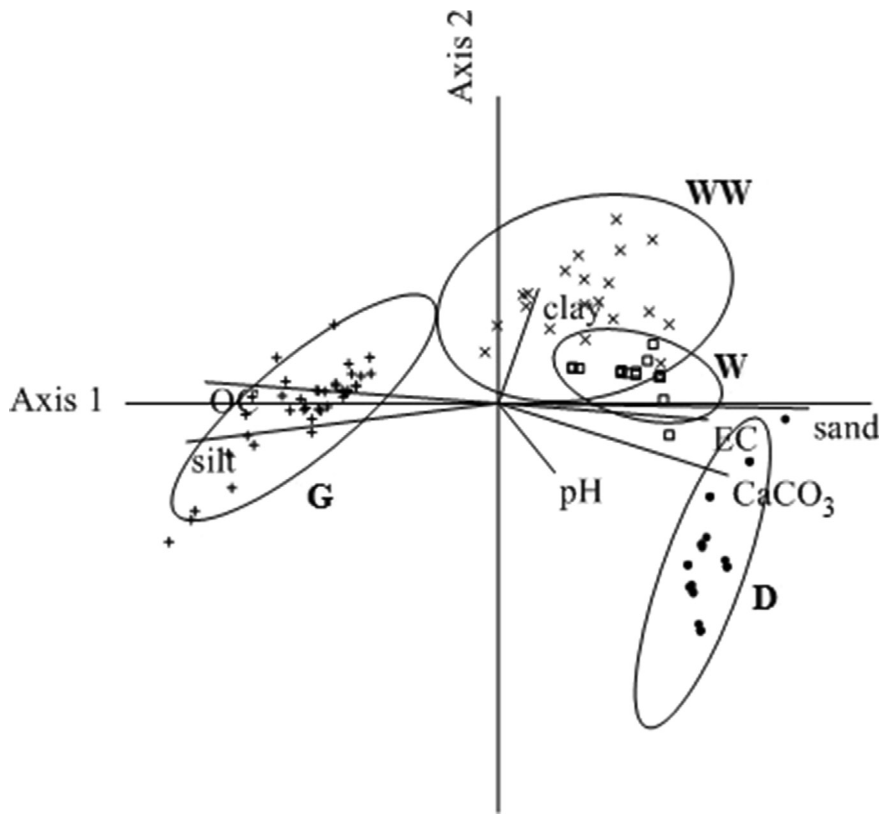

Fig. 4. CCA ordination biplot of stands with soil parameters. OC = soil organic carbon and EC = soil electrical conductivity. The bold capital letters indicate the habitats surveyed; D = desert, W = watery sites, WW = wastewater-affected sites, and G = gardens and parks.

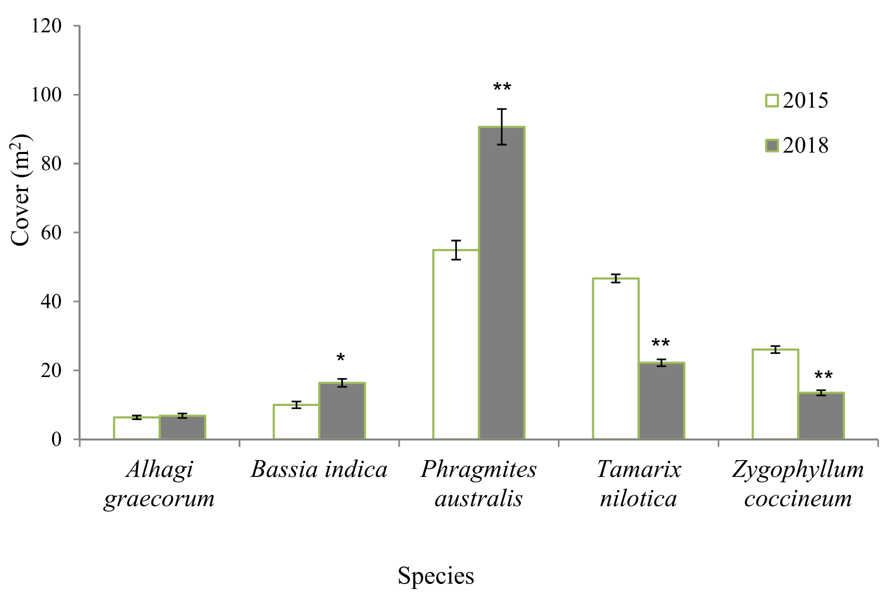

Fig. 5. The cover values of some species (m^2) affected by human activities during urbanization. The cover was measured in 2015 is before urbanization, and in 2018 is after urbanization of desert. Columns represent means and bars represent standard errors. * Significant results from 2015 at $P < 0.05$ due to Paired-Samples T test. ** Significant results from 2015 at $P < 0.01$ due to Paired-Samples T test.

organs (Harper, 1977) and productivity of flowers early in their lifespan to ensure seed output even in a year when the growing season is cut short (Sans and Masalles, 1995). Most of the species detected in this study were commonly recorded in the agro-ecosystem of Beni-Suef governorate (Hegazy et al., 2004; Gomaa et al., 2012) as well as the new urban communities in Egypt (Abd El-Ghani et al., 2011; Hassan, 2018). Thus, most of these species could be dispersed from their own habitat (i. e. the agro-ecosystem) with soil, water and/or wind.

The application of DCA resulted in successful separation of the different habitats in the study area into four vegetation groups, representing the habitats surveyed (desert, watery sites, wastewater-affected sites and gardens), where the full man-made vegetation (gardens and parks) occupied the left end of this gradient to no man-made vegetation (desert habitat) found in the right end. Such classification indicates the significant effects of human activities on the plant community composition. This result is consistent with that obtained by Abd E-Ghani et al. (2012). With respect to the cover values of the species detected with the habitats studied, the significant results (shown in Table 2) suggest that distribution and composition were substantially altered amongst these different locations. This indicates the role of human activities in the new area, i.e. in the direction from D to G along the DCA axis 1. Moreover, the high eigenvalue for DCA axis 1 indicates that most of variations in the floristic composition amongst habitats occur along this axis.

The existence and cover of the species detected in the present study depended on the habitats surveyed. A very few species were detected in desert. Consequently, lower species diversity was obtained. This result could be attributed to the scarcity of water. This result, moreover, matches that of obtained by Gomaa (2012b) who observed very few species in such habitat. On the other hand, the outskirts of the study area do not represent a desert wadi, and, thus, accumulation of water due to rainfall became mostly impossible as this is not catchment microsites. Our finding also showed that the floristic diversity was low in the watery sites (W) appeared during construction activities. This result matches that obtained by Abd El-Ghani et al. (2012) who found a reduced species diversity in the sites of water courses where *Phragmites australis* dominates. The dense canopy such tall growing species around the water bodies may hinder germination and growth of other species; leading to lower species diversity (Shaltout and El-Sheikh, 1993). Moreover, this species can grow in sparse patches and dense monocultures (Lambert et al., 2010).

Appearance of some species such as *Phragmites australis*, *Portulaca oleracea* and *Cyperus laevigatus* in the wastewater-affected sites may agree with field observations reported by Batanouny (1979) and (1981) due to discharge of effluents in the Arabian Peninsula. Presence of some crops such as melons and tomatoes in this habitat reflects the human activities in the residential areas. Washing of vegetables and fruits in kitchens of houses and restaurants may facilitate dispersal of seeds with the underground water and, consequently, carry the seeds of different species to such habitat. Such observation may also be attributed to the undigested seeds of these species commonly eaten and, thereafter, they could disperse with the flowing wastewater.

This study revealed that soil characteristics varied amongst the different habitats. This result confirms soil heterogeneity in newly urbanized areas (Abd El-Ghani et al., 2015). Variation of soil criteria among the habitats surveyed could be attributed to human manipulations. The results due to CCA in this study showed also that the measured soil variables had close correlations with cover values of the plant species in the habitats involved in the study area. These results suggest that the soil parameters markedly influence distribution, composition and diversity of plant communities. The present findings are matching those obtained by Shaltout and El-Sheikh (2002), Hegazy et al. (2004), Pinke et al. (2010) and Gomaa et al. (2012) that indicated the importance of soil texture, salinity and organic carbon for the composition and diversity of plant communities.

The results of this study proved that the cover of *Tamarix nilotica* was suppressed in the desert fragments left inside the city. Moreover, *Zygophyllum coccineum* was completely absent. On the other hand, the cover values of both species were declined from 2015 to 2018. This is due to the overcutting of desert species to pave the ground for construction purposes. The climate in this city seemed to be stable over the short time within the study area (see Table 1). Furthermore, no indication for the spread of disease agents was observed over this period. Consequently, this result suggests that reduction in the cover of some desert species could be attributed to urbanization pressure. This result is also consistent with the facts reported by Batanouny (1983) who indicated that expansion of housing programs and construction activities caused the removal of plant cover from vast areas and enhanced erosion. Destruction of desert vegetation and degradation of this natural ecosystem lead to retrogressive changes in plant life of new urbanized deserts. Such overcutting of the desert species may also lead to apparent reduction in species diversity as indicated in our results. On the otherhand, presence of *Alhagi graecorum* in the desert fragments inside the city may reflect the human activities close to such points. In this regard, human-mediated dispersal of seeds by the airflow of vehicles has been indicated (von der Lippe et al., 2013). Moreover, the man-made barriers in the urban systems may hinder more dispersal of the seeds of such species. The results also revealed that the measured edaphic factors of the desert sectors found inside and outside the city were statistically similar. Therefore, it is so difficult to claim that presence or absence of a given species in both locations was attributed to the soil factors.

On the other hand, the land cover of *Phragmites australis* was also increased over time. Induction of its cover was attributed to liberation and accumulation of more amounts of water in shallow depressions formed around the pipelines. More water was accompanied with more construction activities. This result was consistent with results observed by Batanouny (1981) who reported the dense growth of the common reed as a result of uncontrolled spilling of water. This species is extremely difficult to be removed once established (Lambert et al., 2010). In addition, this species is considered an ecological indicator for water. The results also showed that the cover of such species was related to sand, clay and salinity. This result is typically consistent with that obtained by Serag (1996). Therefore, combination of the presence of these soil factors in addition to water engendered the growth of this species. Similarly, the present investigation manifested that the cover of *Bassia indica* was significantly induced in 2018 (i.e. after human activities) compared with 2015. This result suggests that the human activities enhance the invasive character of this species. In this regard, Lechuga-Lago et al. (2017) pointed out that human disturbed areas might be more easily invaded than natural areas.

Vegetation of the desert in the present study area suffers from human activities such as overcutting for construction purposes, leading to noticeable degradation for the natural habitat and vegetation destruction in some areas. Amongst 53 species detected in this study, only 4 species were observed in the desert. Amongst them, *Tamarix nilotica* and *Zygophyllum coccineum* are likely to be vulnerable to elimination from their natural habitats over years due to extension of urbanization. Reestablishment of these species would be difficult and slow if demolished, particularly if we know that there were dissimilarity between soil seed bank and the above-ground vegetation in the desert (Gomaa, 2012b). Therefore, much attention should be paid to overcome or, at least, reduce the negative impact of urbanization on the native plants within a given area.

5. Conclusion

Floristic composition and diversity clearly varied among the different habitats studied in a newly urbanized ecosystem, the result that was clearly indicated by the DCA which successfully separated the habitats investigated. Urbanization led to introduction of several weed species into the new area. Appearance of some cultivated species in the wastewater-affected sites (WW) suggests the apparent human manipulations. In addition, the soil characteristics were significantly altered across the study area. This change happened in soil could be attributed to human settlements. Moreover, changing of soil criteria had, at least, a partial effect on distribution, cover, composition and diversity of plants found in the habitats studied. On the other hand, the cover of the desert species; particularly *Tamarix nilotica* and *Zygophyllum coccineum*, was significantly decreased over years due to destruction of desert vegetation for more urbanization. The opposite was correct for *Phragmites australis* and *Bassia indica*. Release of more water during construction activities or from the underground sewers could be a factor for extensive increase in cover of the common reed (*P. australis*). Such result also indicates that more human activities in the desert might favor establishment of the invasive *B. indica*. These results suggest the substantial role of human activities and, in turn, urbanization, on vegetation. Conservation strategies should be devoted to save some species that are vulnerable to elimination from the desert due to expansion of urbanization.

Declarations

Author contribution statement

Mahmoud O. Hassan: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Yasser M. Hassan: Contributed reagents, materials, analysis tools or data.

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