Plant Distribution Patterns in the Urbanized Habitats of Kharga and Dakhla Oases, Western Desert, Egypt

Monier M. Abd El-Ghani[1*], Marwa M. Ragaie[2], Salwa Abd El-Wahab[2], Ali El-Saied Gaafar[2]

[1] Botany and Microbiology Department, Faculty of Science, Cairo University, Giza 12613, Egypt.

[2] Botany and Microbiology Department, Faculty of Science, New Valley University, EL-Kharga 71511, Egypt.

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Abstract

This study investigates the relationship between vegetation and soil characteristics supporting urban habitats in Kharga and Dakhla Oases, Egypt. A total of 39 permanently visited sampling plots across the habitats in Dakhla and Kharga Oases to represent the apparent variation in the different habitats. Four main habitat types were identified: home gardens (HG), public gardens (PG), road islands (RI), and vacant lots (VL). These plots were distributed as follows: 11 in public gardens, 16 in home gardens, 8 in road islands, and 4 in vacant lots. The largest families that formed the main bulk of the recorded flora were Fabaceae (29 species, 17% of the total flora), followed by Poaceae (21 species, 12%), and Asteraceae (12 species, 7%). Other less important families included Amaranthaceae (9 species, 5%), Malvaceae (8 species, 5%), Brassicaceae, Convolvulaceae, Euphorbiaceae (6 species for each, 4%), and Apocynaceae (5 species, 3%). There were 20 mono-specific families constituted 38.4% of the total families represented by one species. Cluster analysis classified the vegetation into 14 distinct groups, revealing species compositions characteristic of each habitat, highlighting the significant influence of human activities, such as urbanization and agricultural practices, on species composition. Managed habitats, particularly home gardens (HG) and public gardens (PG), exhibited the highest species richness, hosting a diverse mix of native, cultivated, and ornamental species. Home gardens, with 132 species, were characterized by fruit trees and native xerophytes, while public gardens, with 112 species, supported ornamental plants and wetland species. In contrast, disturbed habitats such as road islands (RI) and vacant lots (VL) were dominated by weeds and xerophytic species, adapted to harsh, unmanaged conditions. Road islands with 71 species and vacant lots, with only 58 species, were the least diverse, reflecting the challenging environmental conditions of these unmanaged areas. Multivariate analyses, including cluster Analysis and Canonical Correspondence Analysis (CCA), revealed significant differences in the composition of vegetation clusters across habitats, affected by soil properties such as moisture content, salinity, and nutrient availability. Soil variables like electrical conductivity, total soluble salts, and chloride content were particularly influential in shaping species distribution in saline environments, while organic matter and clay content played key roles in managed habitats. These findings highlight the influence of habitat type on species distribution and the ecological dynamics of vegetation in arid oasis environments.

Keywords: Urban ecology; Synanthropic vegetation; Flora; Soil-vegetation relationships; Multivariate analysis.

Introduction

Urban environments support diverse plant species, from naturally occurring flora in disturbed areas to cultivated ornamental plants in managed spaces [56]. Urban vegetation includes both spontaneous and intentionally planted species. Synanthropic plants, shaped by human activities, thrive in urban areas, agricultural fields, and ruderal habitats like waste sites, railways, and road verges [16, 38]. Research on urban vegetation has grown, focusing on biodiversity [42, 67], plant composition changes [21, 47], species distribution [23], fragmentation [10, 26], and alien species introduction [48, 24]. Despite increased interest, studies on ecological variables influencing plant distribution remain limited [43, 54]. A knowledge gap in urban ecology limits baseline data and its application in urban planning [46]. Studies indicate a strong link between species richness and population size [36, 49]. Land-use impacts have been examined in Plymouth [34], Berlin [44], and Almería, Spain [18]. Urban ecosystems present challenges like pollution, habitat fragmentation, and physical disturbances, restricting native flora [25]. Cities have distinct species compositions shaped by initial plant populations [55]. Synanthropic vegetation, strongly influenced by human activity, is central to urban ecology research [43, 54]. It includes weeds in agricultural fields and ruderal species in disturbed areas [38]. While widely studied in Europe, urban vegetation remains underexplored in many regions [18]. Urban plant research focuses on biodiversity [3, 42, 37], species distribution [23], fragmentation [53],

*Corresponding authors: monierabdelghani@yahoo.com

and alien species [48]. Alien plants comprise 20–60% of urban flora in Central Europe [47]. Land use is a major factor in species distribution [2, 55]. Cities are classified into ecological zones [27, 35], with extensive studies on flora-vegetation relationships [50, 17].

Urban-industrial ecosystems differ from non-urban environments due to factors like shading, hard surfaces, pollution, and combustion heat [67]. Cities form unique ecological settings with distinct species compositions [56]. Species diversity in urban-industrial areas results from land-use diversity, non-native species introduction, human-driven speciation, and overall habitat richness [66]. Studies highlight species richness in cities due to habitat diversity and alien species introduction [22, 48]. In Egypt, new cities aim to redistribute the population, ease urban congestion, and prevent farmland encroachment. These cities are near major population centers like Cairo, Giza, and Alexandria, while others, such as New Safaga, are along the Red Sea. Beyond their natural origins, oases are human-altered landscapes that have been cultivated and managed in the Sahara since at least the third millennium BCE [45]. The southern oases, Dakhla and Kharga, are focal points for expansion due to their fertile soils and abundant groundwater resources [32, 6]. However, studies that focused on the ecological dynamics of urban vegetation in arid oases, where high habitat heterogeneity and human activities shape species distribution patterns are lacking. For this reason, this study has been achieved to fill this gap and presents as much as possible the baseline information for further studies in the area.

The present study will be conducted in Two desert oases of the Western Desert of Egypt: Kharga and Dakhla Oases aiming to: 1) recognize the main urban habitats dominating the studied areas, 2) identify the floristic composition and evaluate the plant species diversity in the recognized habitats, 3) demonstrate the spatial distribution ranges of species, 4) analyze, quantitatively, the vegetation units (plant communities) that characterize the urban habitats, and 5) assess the role of the prevailing environmental variables that affect distribution of the recognized plant communities.

Materials and methods

Study areas

Kharga and Dakhla Oases, known as the "New Valley," are located in the Nubian region of Egypt's Western Desert [19]. Kharga spans approximately 7,200 km² and lies southwest of Assiut, while Dakhla covers around 2,000 km², positioned west of Kharga and the Nile Valley. Both oases feature depression floors composed of non-fossiliferous brown sandstone, lying below the surrounding plateau [52]. Water availability is the primary factor sustaining life in these arid environments. Irrigation relies on natural springs and wells, with a system of side channels optimizing limited water resources [1]. Agriculture in both oases is groundwater-dependent, with water believed to originate from Equatorial Africa's rainfall infiltrating deep aquifers [14]. Kharga and Dakhla are distinguished by their abundant and high-quality water supply.

Agriculture in the region relies entirely on artesian wells, some dating back to Pharaonic and Roman times. However, many of these old wells have been abandoned due to sand encroachment or reduced artesian pressure. To improve water access, modern deep wells (250–850m) with higher discharge rates have been drilled [1]. Vast cultivated areas are dominated by date palm (*Phoenix dactylifera* L.) and dom-palms (*Hyphaene thebaic***a** L.). Key crops include clover, wheat, barley, and broad beans in winter, while maize is the primary summer crop. Alfalfa (*Medicago sativa* L.) is also grown as a cash crop. The region falls within a hyper-arid bioclimatic zone, experiencing minimal rainfall and extreme aridity [8, 4].

Vegetation sampling

Between February and September 2023, the vegetation was sampled from 39 permanently visited plots across Dakhla and Kharga Oases (Figure 1), selected to include physiognomic variation in habitats, geo-referenced using GPS with altitudes ranging from 98 to 168 m above sea level (**Appendix 1**). Each sample plot was approximately 20 m × 20 m, the minimal area for species associations in the study area [51]. Four main habitats were recognized: public gardens, home gardens, road islands, and vacant lots. The distribution of sample plots in the studied habitats was as follows: 11 in public gardens, 16 in home gardens, 8 in road islands, and 5 in vacant lots. Species presence or absence was recorded using permanent plots randomly positioned to represent habitat floristic composition. For each species in each habitat, occurrence percentages (f%) were calculated as the number of sample plots where the species was recorded divided by the total plots representing the habitat. The collected plant specimens were identified at the Cairo University Herbarium (CAI), taxonomic nomenclature was according to [57] and updated by [13]. The main electronic sources and online global databases were used are: Plants of the World Online (POWO; http://www.plantsoftheworldonline.org), International Plant Names Index (IPNI; http://www.ipni.org), and World Flora Online (WFO; https://www.worldfloraonline.org), WFO Plant List (https://wfoplantlist.org/plant-list). Each of the recorded species was assigned to either native (N) or non-native (NN) using the online global database Plants of the World Online (POWO; http://www.plantsoftheworldonline.org).

Table .1 Means of monthly records from the five years (2019–2023) of some climatic features at the nearest meteorological station to the study areas (Courtesy of the Meteorological Station, Kharga Oasis).

Months	Temp. (°C)		Rainfall (mm)	Relative Humidity (%)	Wind Velocity (km Hour^{-1})
	Max.	Min.			
Jan.	18	5	0.25	39	9.88
Feb.	19	6	0.12	30	10.37
Mar.	20	7	0.07	22	12.06
Apr.	25	8	0.02	19	13.94
May	30	9	0	15	15.06
Jun.	32	11	0	16	11.76
Jul.	34	12	0	19	10.72
Aug.	35	13	0	20	8.81
Sep.	30	6	0	21	11.09
Oct.	25	5	0	26	11.69
Nov.	20	4.5	0	38	8.31
Dec.	18	3	0.05	40	9

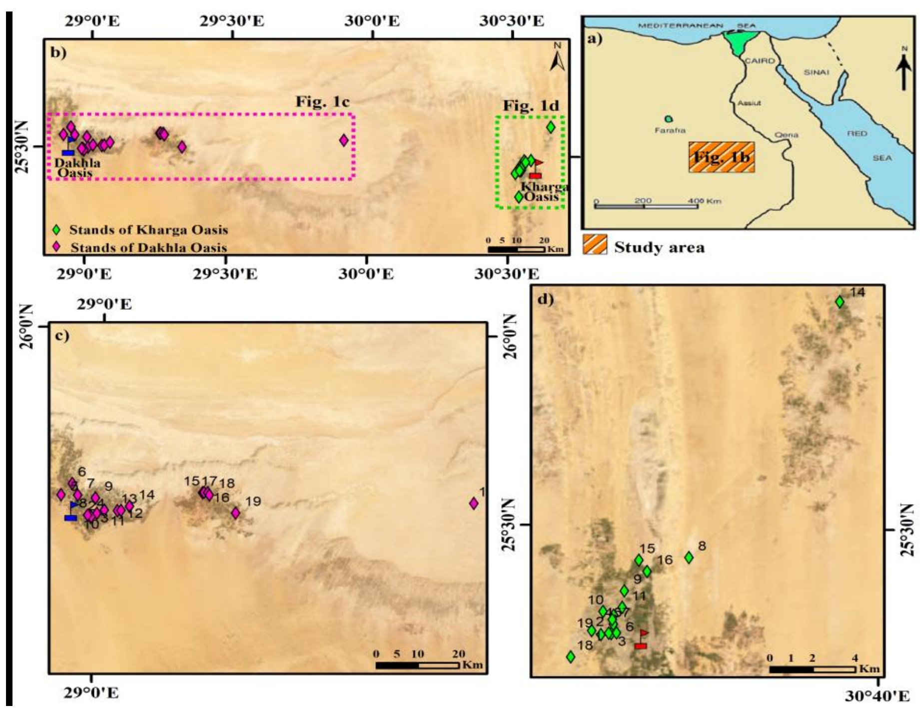

Figure 1. Location map of Dakhla and Kharga Oases showing the studied sample plots, Dakhla (red color) and Kharga (green color).

From each sampled plot, one composite soil sample was collected from three different places (0-30 cm), air-dried, thoroughly mixed, and passed through a 2 mm-sieve to get rid of gravel and boulders. Finer size particles less than 2 mm were kept for physical and chemical analysis [30, 7]. Soil texture was determined by the hydrometer analysis [15], and the results were used to calculate the percentages of coarse sand, fine sand silt and clay. Soil moisture (WC) content was estimated by drying at 105°C, and then the percentage of soil moisture was calculated based on dry weight of the soil [33]. Soil reaction (pH) and electrical conductivity (EC) were evaluated in 1:5 soil-water extract using a glass electrode pH-meter and electric conductivity meter (model 4310 JEN WAY), respectively. The concentrations of chlorides (Cl) in soil extract samples were determined by silver nitrate ($AgNO_3$) titration method as described by [30]. Sulfates (SO_4) were determined by a turbidimetric technique such as ($BaSO_4$) using barium chloride and acidic sodium chloride solution using spectrophotometer (model 1200) according to [9]. Phosphates (PO_4) were determined calorimetrically as phospho-molybdate according to [64]. Sodium (Na) and potassium (K) were determined by the flame emission technique (Carl-Zeiss DR LANGE M 7 D) flame photometer was used, which is considered as a rapid and sensitive method for determination of sodium and potassium [63]. Calcium (Ca) and Magnesium (Mg) were determined volumetrically by versine titration method as described by [11]. The carbonate content (CO_3) content was determined using 1N HCl using phenolphthalein indicator [30]. The percentage of organic matter (OM) content was determined in the soil samples by the dichromate oxidation method according to [62].

Vegetation analysis and data processing

Multivariate approaches of classification and ordination were used to analyze and define vegetation data, and to examine their relationships with the environmental variables studied. The cluster analysis was conducted using Community Analysis Package (CAP) version 1.2 for Windows [28] and all ordinations were performed using the software CANOCO version 4.5 for windows [60]. Three complementary analyses were used in this study:

First, the presence/absence plot-species dataset of 39 sample plots and 112 species (after removal of species with less than 5% occurrence) was classified by a hierarchical, agglomerative cluster analysis. In order to examine the constancy of the obtained results, different classification algorithms were applied: single linkage, complete linkage, unweighted paired group method average (UPGAMA) using Euclidean distance, and Ward (minimum variance) clustering method using squared Euclidean as distance measure. Despite the differences between the classification methods, the results were similar, however, the Ward (minimum variance) method was used in the analysis.

Second, a Detrended Correspondence Analysis (DCA; [29]) was applied to check the magnitude of change in species composition along the first ordination axis species in the data set. The length of gradient in estimated in standard deviation (SD) units. In this study, the length of gradient along the first DCA axis was 3.11 SD. Therefore, the appropriate analysis is Canonical Correspondence Analysis (CCA) to indicate vegetation-environment relationships [58] .

Third, CCA was performed to examine the relationships between vegetation gradients and the studied soil variables, and a Monte Carlo permutation test (499 permutations; [59]) was used to test the significance of the eigenvalues of the first canonical axis. Prior analysis, all soil variables were checked for normality and suitable transformations were applied. Soil variables with high inflation factors were removed from CCA analysis [31], and 11 variables were used including coarse sand (CS), fine sand (FS), clay, moisture content (WC), electrical conductivity (EC), soil reaction (pH), organic matter (OM), sodium (Na), sulfates (SO_4), phosphates (PO_4), and carbonates (CO_3). Significant variations among cluster groups were then subjected to ANOVA (One-Way Analysis of Variance) using SPSS version 16.0 for windows.

Species diversity measurements

The species richness (SR) for each cluster group was calculated based on the frequency (f%) of each species as the average number of species per sample plot. Additionally, the Shannon diversity index (H′) was used to assess relative species evenness, following the formula $H' = -\Sigma P_i \log P_i$; where $P_i = N_i/N$, N_i is the number of individuals of species i, and N is the total number of individuals across all species [39]. SR and H′ represent the α-diversity of vegetation in relation to the sample plot size (400 m²) and are widely used in ecological studies [40,65].

Results

Species distribution patterns within habitats

Four main urban habitats were distinguished: public gardens (PG), home gardens (HG), vacant lots (VL) and road islands (RI). The most species rich habitat was the home gardens (132 species), while the total number of species varied from 112 in the public gardens and 71 species in the road islands and 58 species in the vacant lots (Table 2). Perennials constituted the main bulk of the flora. They showed remarkable occurrence of 90 species (52% of the total flora), perennial herbs and woody perennials dominated in the home gardens (70 species (40% of the flora), followed by road island (30 species, 17% of the flora), public gardens (19 species, 11% of the flora) and vacant lots (17 species (10% of the flora). Annuals were represented by 83 species (47.9% of the total flora), dominated in home gardens (61species (35% of the flora), followed by public gardens (54 species, 31% of the flora), road island (40 species, 23% of the flora) and vacant lots (22 species (13% of the flora). Fabaceae, Poaceae, Asteraceae, Amaranthaceae, Malvaceae, Brassicaceae, Convolvulaceae and Euphorbiaceae were the most species-rich families and their species were represented in all habitats (Table 2, Figure 2).

Some of the cultivated plants were also recorded e,g., fruit trees such as *Mangifera indica, Morus alba, Morus nigra, Psidium guajava,* and *Musa nanensis*; fence or hedge plants such as *Dodonaea viscosa, Lantana camara, Jasminum grandiflorum,* and *Bougainvillea glabra*; woody trees used for house roofing and other domestic purposes such as *Eucalyptus globulus, Allocasuarina distyla, Ziziphus spina-christi, Melia azedarach,* and *Sesbania sesban;* vegetable herbs such as *Anethum graveolens, Coriandrum sativum, Petrosilinum crispum, Solanum lycopersicum,* and *Abelmoschus esculentus.*

It can be noted that that weed species had the highest contribution (40%) in road islands, while ornamentals exhibited a more uniform distribution across habitats, ranging from 8.9% in vacant lots to 16.2% in public gardens. Home and public gardens were characterized by fruit trees and cultivated herbs typically used for domestic purposes, such as *Citrus limon*, *Musa nana*, *Cucurbita pepo*, *Morus alba*, *Olea europaea*, *Hibiscus sabdariffa*, and *Anethum graveolens*. In contrast, vacant lots, which are predominantly desert areas, were dominated by several xerophytic species (35.5%) and salt-tolerant species (9.0%). Dominant species in this habitat included *Imperata cylindrica*, *Tamarix nilotica*, *Phragmites australis*, *Prosopis fracta*, *Pulicaria undulata*, and *Alhagi graecorum*.

Classification of the vegetation

The resulted cluster vegetation groups were named after the dominant and highly abundant species with the higher frequency percentages (f%). Table (3) summarizes the recorded species within each vegetation group identified through cluster analysis for the four main habitat types: public gardens (PG), home gardens (HG), road islands (RI), and vacant lots (VL). The table highlighted the dominant and characteristic species for each group, along with their highest percentages, providing a clear overview of species composition and distribution across the different habitats. This summary underscores the ecological variability and species preferences within each habitat, reflecting the influence of environmental factors such as soil properties and human management practices on vegetation patterns.

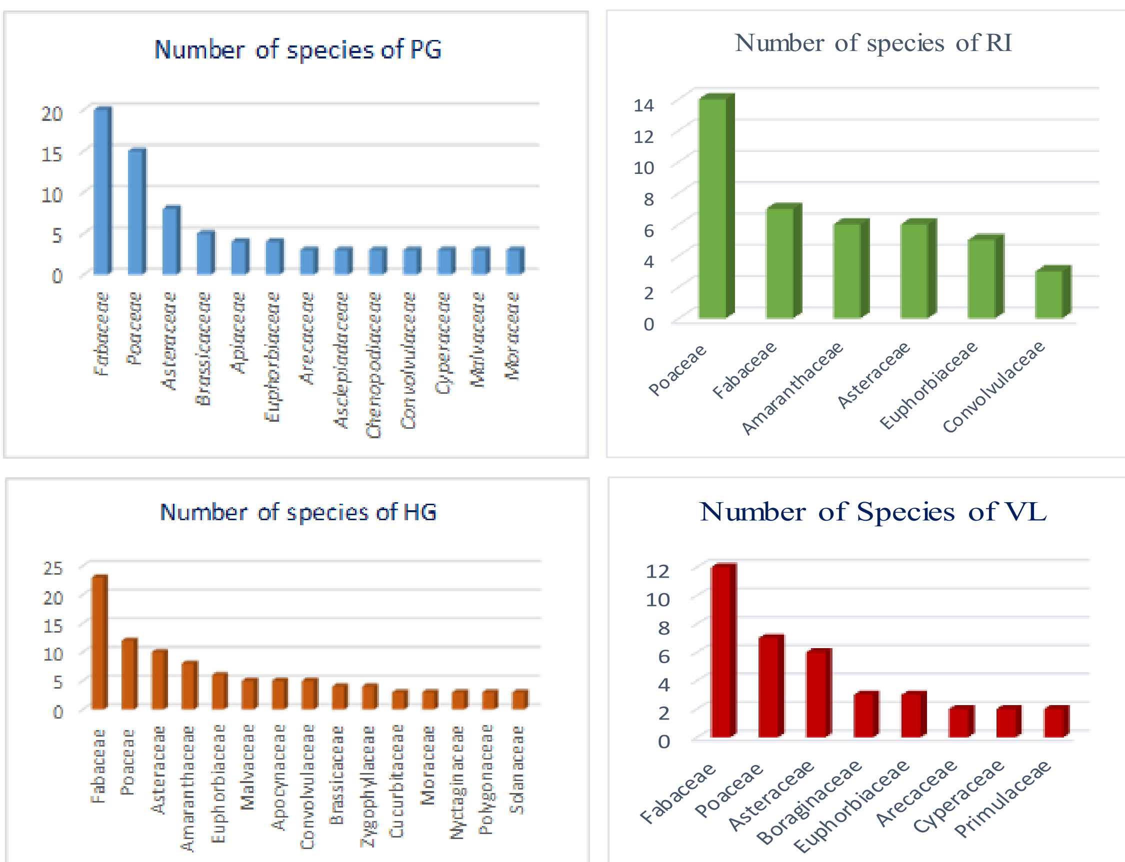

Figure 2. Species-rich families in the four habitats: PG=Public gardens, HG= Home gardens, RI= Road Island and VL= Vacant lots.

Table 2. Summary of the floristic structure, including families, in the 4 habitats; PG=Public gardens, HG=Home gardens, VL=Vacant lots and RI=Road Island. Percentages of each habitat are between parentheses, figures are the number of species within each family.

Habitats	PG	HG	RI	VL
Total number of plots	11	16	8	5
Total number of species	112	132	71	58
(I) Growth forms				
i) Annuals	54 (31%)	61 (35%)	40 (23%)	22 (13%)
ii) Perennial herbs	19 (11%)	70 (40%)	30 (17%)	17 (10%)
iii) Woody perennials	31 (18%)	37 (21%)	11 (6%)	19 (11%)
(II) Species-rich families				
Fabaceae	20	23	7	12
Poaceae	15	12	14	7
Asteraceae	8	10	6	6
Amaranthaceae	1	8	6	1
Malvaceae	3	5	2	2
Brassicaceae	5	4	2	2
Convolvulaceae	3	5	3	1
Euphorbiaceae	4	6	5	3
Apocynaceae	2	5	2	1
Cyperaceae	3	2	2	2
Zygophyllacea	1	4	1	1
Arecaceae	3	2	1	2
Moraceae	3	3	1	1
Nyctaginaceae	2	3	2	1
Solanaceae	1	3	1	1
Primulaceae	2	2	2	2
Tamaricaceae	1	2	1	1
Oleaceae	2	2	1	1
Polygonaceae	1	3	1	0
Apiaceae	4	0	0	0
Asclepiadaceae	3	0	0	0
Boraginaceae	2	2	0	3
Chenopodiaceae	3	0	0	0
Cucurbitaceae	0	3	1	0
Lamiaceae	2	2	0	0
Caryophyllaceae	1	1	1	0
Casuarinaceae	0	2	0	0
Myrtaceae	0	2	0	1
Plantaginaceae	2	1	1	0

The application of cluster analysis yielded 14 vegetation groups in the identified habitats (Figure 3). Each group will be referred her to as cluster vegetation group, and named after the dominant and highly abundant species. The classification of 11 sample plots from public gardens habitats resulted in 3 groups in the public gardens: group (A) dominated by *Cynodon dactylon - Melilotus siculus - Alhagi graecorum - Erigeron bonariensis*, group (B) dominated by *Dicanthium annulatum -Phoenix dactylifera*, and group (C) dominated by *Imperata cylindrica - Ziziphus spina-christi*. The classification of the 16 plots from home gardens resulted in five vegetation groups and named after the dominant and highly abundant species. The five plot groups in the Home gardens were: group (A) dominated by *Cynodon dactylon* - *Chenopodiastrum murale* - *Melilotus siculus*, group (B) dominated by *Cynodon dactylon - Sonchus oleraceus - Sorghum halepense - Trifolium alexandrinum),* group (C)) dominated by *(Imperata cylindrica - Eruca sativa - Chenopodiastrum murale*), group (D*)* dominated by *Ziziphus spina-christi - Sesbania sesban - Boerhavia diffusa - Echinochloa colonum*, and group (E) dominated by *Cynodon dactylon* - *Olea europaea - Coincya tournefortii*. The classification of 8 plots from road islands in studied sample plots of Kharga and Dakhla oases resulted in 4 cluster groups, group (A) dominated by *Portulaca oleracea - Sonchus oleraceus - Medicago sativa - Tribulus pentandrus*, group (B) dominated by *Chenopodiastrum murale - Amaranthus viridis - Dicanthium* *annulatum*, group (C) dominated by *Tamarix nilotica* - *Cenchrus ciliaris* - *Ziziphus spina-christi* - *Phragmites australis,* and group (D) dominated by (*Convolvulus arvensis* - *Lysimachia arvensis* var. *caerulea* - *Lysimachia arvensis* subsp. *arvensis.* The classification of the 5 plots from vacant lots resulted in 2 groups: group (A) dominated by *Tamarix nilotica* - *Imperata cylindrica*- *Malva parviflora* and group (B) dominated by *Alhagi graecorum* - *Phragmites australis* - *Prosopis farcta.*

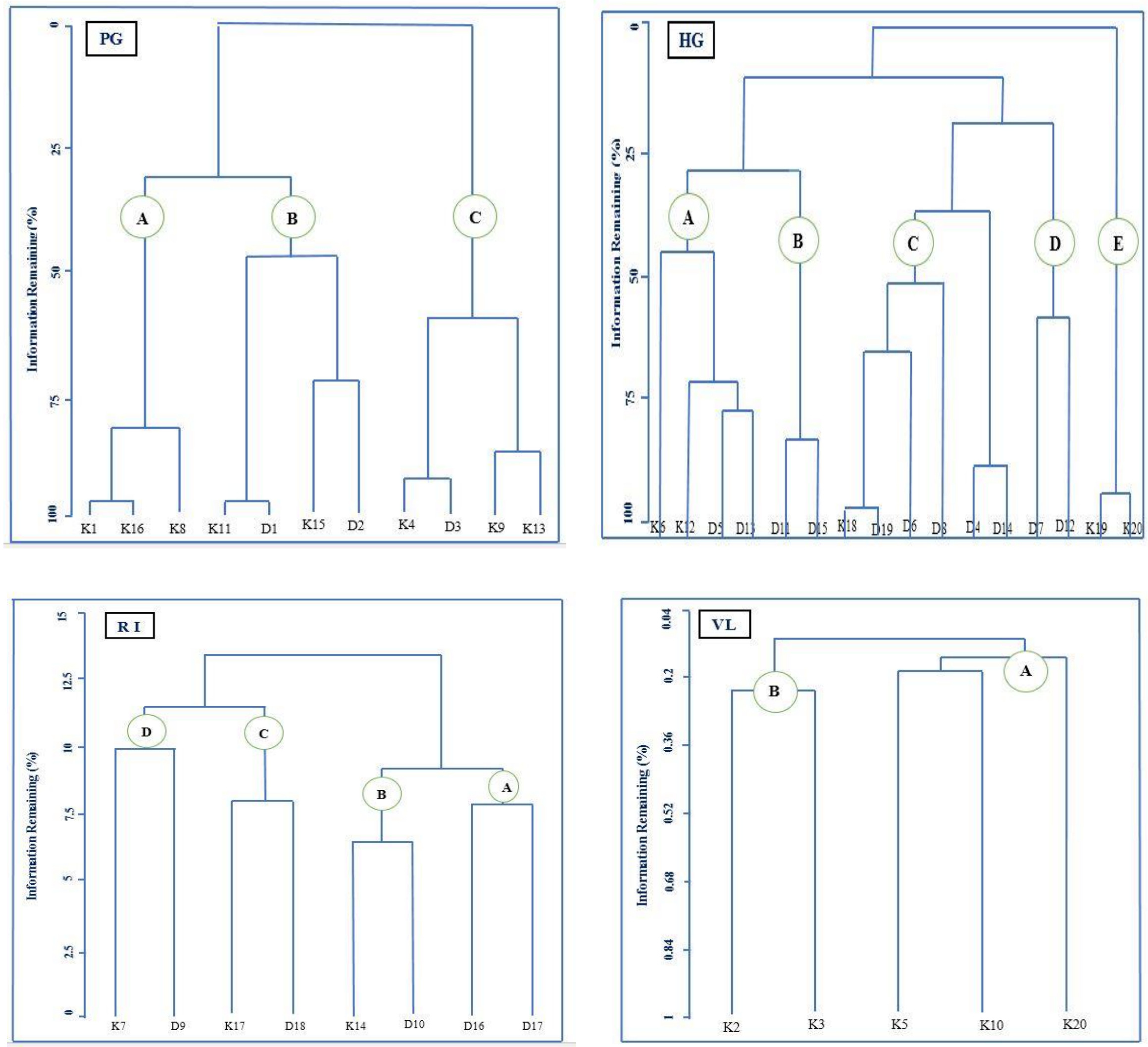

Figure 3. The 14 vegetation groups yielded after the application of cluster analysis for classification of vegetation in the four habitats: PG=Public gardens, HG=Home gardens, RI=Road Island and VL=Vacant lots

Table 3. Sociological ranges of species are recorded in the studied habitats, with their numbers and percentages of occurrences (f%). HG=Home gardens, PG=Public gardens, RI=Road islands, VL=Vacant lots.

Habitat	HG		PG		RI		VL	
Total number of plots	16		11		8		5	
Total number of cluster groups	5		3		4		2	
	No	f%	No	f%	No	f%	No	f%
Species present in all habitats (most common)								
Cynodon dactylon (L.) Pers.	15	94	10	91	7	88	1	25
Melilotus siculus (Turra) Steud.	8	50	9	82	7	88	2	50
Tamarix nilotica (Ehrenb.) Bunge.	4	25	5	45	4	50	3	75
Alhagi graecorum Boiss.	4	25	6	55	1	13	4	100

Table 3. (Continued)

Species present in all habitats (most common)	HG		PG		RI		VL	
	No	f%	No	f%	No	f%	No	f%
Malva paviflora L.	6	38	3	27	6	75	2	50
Ziziphus spina-christi (L.) Desf.	7	44	6	55	3	38	2	50
Sonchus oleraceus L.	9	56	6	55	4	50	1	25
Dicanthium annulatum (Forssk.) Stapf.	5	31	7	64	5	63	1	25
Phragmites australis (Cav.) Trin. ex Steud.	5	31	4	36	2	25	3	75
Cenchrus ciliaris L.	3	19	6	55	3	38	1	25
Lactuca serriola L.	2	13	4	36	2	25	2	50
Medicago sativa L. subsp. *sativa*	3	19	3	27	4	50	1	25
Convolvulus arvensis L.	5	31	3	27	2	25	1	25
Euphorbia prostrata Aiton.	1	6	3	27	4	50	1	25
Sorghum halepense (L.) Pers.	5	31	3	27	2	25	1	25
Eruca vesicaria (L.) Cav.	8	50	2	18	1	13	1	25
Euphorbia hirta L.	3	19	4	36	2	25	1	25
Lysimachia arvensis (L.) U. Manns & Anderb. var. *caerulea* (L.) Turland & Bergmeier.	3	19	4	36	2	25	1	25
Brassica tournefortii Gouan	5	31	2	18	2	25	1	25
Calotropis procera (Aiton)W.T. Aiton	3	19	3	27	2	25	1	25
Launaea mucronata (Forssk.) Muschl.	3	19	3	27	2	25	1	25
Bougainvillea glabra Choisy.	4	25	2	18	1	13	1	25
Hyphaene thebaica (L.)Mart.	3	19	2	18	1	13	1	25
Cyperus longus L. subsp. *longus*	1	6	1	9	1	13	1	25
Ricinus communis L.	1	6	1	9	1	13	1	25
Species present in three habitats (common)								
Phoenix dactylifera L.	13	81	8	73			2	50
Chenopodium murale (L.) S.Fuentes,Uotila & Borsch.	11	69	7	64	5	63		
Imperata cylindrica (L.) Raeusch.	8	50	6	55			3	75
Portulaca oleracea L.	3	19	5	45	5	63		
Sesbania sesban (L.) Merr.	4	25	5	45			2	50
Trifolium resupinatum L. var. *resupinatum*	2	13	6	55	3	38		
Erigeron bonariensis L.	4	25	7	64	1	13		
Pluchea dioscoridis (L.) DC.	1	6	4	36			2	50
Tribulus terrestris L.	2	13	3	27	4	50		
Amaranthus viridis L.	3	19	3	27	3	38		
Olea europaea L.	8	50	1	9	2	25		
Prosopis fracta (Branks & Sol.)J.F.Macbr.	2	13	1	9			2	50
Lysimachia arvensis (L.) U.Manns & Anderb. subsp. *arvensis*.	3	19			2	25	1	25
Hyoscyamus muticus L.	3	19			2	25	1	25
Corchorus trilocularis L.	4	25	2	18			1	25
Cordia myxa L.	3	19	2	18			1	25
Boerhavia diffusa L.	4	25	1	9	2	25		
Echinochloa colonum (L.) Link	4	25	1	9	2	25		
Dalbergia sisso Roxb.ex DC.	2	13	2	18			1	25
Chenopodium album L.	3	19	1	9	2	25		
Plantago lagopus L.	3	19	1	9	2	25		
Cuscuta campestris Yunck.	2	13	1	9	2	25		
Hibiscus sabdariffa L.	2	13	1	9			1	25
Dodonaea viscosa Jacq.			1	9	1	13	1	25
Cassia fistula L.	1	6	1	9			1	25
Vicia monantha Retz.	1	6	1	9	2	25		

Table 3. (Continued)

Species present in three habitats (common)	HG	PG	RI	VL	HG	PG	RI	VL
	No	f%	No	f%	No	f%	No	f%
Euphorbia peplus L.	1	6	2	18	1	13		
Sorghum varigatum (Hack.) Stapf	1	6	2	18	1	13		
Ficus nitidifolia Bureau.	2	13	1	9	1	13		
Tecoma stans (L.) Juss.ex Kunth.	1	6	1	9	1	13		
Lawsonia inermis L.	1	6	1	9	1	13		
Species present in two habitats (frequent)								
Lolium rigidum Gaudin	3	19			4	50		
Moringa oleifera Lam.	5	31	2	18				
Beta vulgaris L.	1	6			3	38		
Diplachen fusca (L.)P.Beauv.ex Roem.&Schult.			2	18	2	25		
Nerium oleander L.	1	6	4	36				
Oxalis corniculata L.	1	6	4	36				
Citrus limon (L.) Osbeck.	1	6	4	36				
Bassia indica (Wight) A.J.Scott.	4	25			1	13		
Pulicaria undulata (L.) C.A.Mey. subsp. *Undulata*	2	13					1	25
Citrullus colocynthis (L.) Schrad.	2	13			2	25		
Astragalus vogelii(Webb.) Bornm.	3	19	2	18				
Ocimum basilicum L.	3	19	2	18				
Cenchrus divisus (J.F.Gmel.)Verloove, Govaerts & Butter.			1	9			1	25
Mangifera indica L.	2	13	2	18				
Bidens pilosa L.	2	13	2	18				
Trichodesma africanum (L.) Sm.	2	13	2	18				
Cyperus difformis L.	1	6					1	25
Scirpus maritimus L.			2	18	1	13		
Morus alba L.	2	13	2	18				
Poa annua L.			2	18	1	13		
Vigna unguiculata (L.) Walp.	3	19	1	9				
Morus nigra L.	3	19	1	9				
Solanum nigrum L.	3	19	1	9				
Conocarpus lancifolius Engl.	2	13			1	13		
Digitaria sanguinalis (L.) Scop.	2	13			1	13		
Vinca rosea L.	1	6	2	18				
Brassica nigra (L.) Koch	1	6	2	18				
Trigonella glabra Thunb.	1	6	2	18				
Vachellia nilotica (L.) P.J.H.Hurter &Mabb.	1	6	2	18				
Lathyrus hirsutus L.	2	13	1	9				
Cascabela thevetia (L.) Lippold	1	6			1	13		
Euphorbia geniculata Ortega.	1	6			1	13		
Dactyloctenium aegyptium (L.) Willd.	1	6			1	13		
Polygonum equisetiforme Sm.	1	6			1	13		
Suaeda aegyptiaca (Hasselq.)Zohary	1	6	1	9				
Cynanchum acutum L. subsp. *acutum*	1	6	1	9				
Carthamus tinctorius L.	1	6	1	9				
Tagetes tenuifolia Cav.	1	6	1	9				
Stellaria pallida (Dumort.)Crep.	1	6	1	9				
Cressa cretica L.	1	6	1	9				
Bauhinia varigata L.	1	6	1	9				
Mimosa pudica L.	1	6	1	9				

Table 3. (Continued)

Species present in two habitats (frequent)	HG	PG	RI	VL	HG	PG	RI	VL
	No	f%	No	f%	No	f%	No	f%
Abutilon panosum (G.Forst.)Schltdl.	1	6	1	9				
Jasminum grandiflorum L.	1	6	1	9				
Lantana camara L.	1	6	1	9				
Species present in one habitat (unique)								
Opuntia ficus-indica (L.) Mill	5	31						
Psidium guajava L.	4	25						
Cichorium endivia L. subsp. *divaricatum* (Schousb)P.Dsell	3	19						
Ipomoea pes-caprae (L.) R.Br.	3	19						
Luffa aegyptiaca Mill.	3	19						
Trifolium alexandrinum L.	3	19						
Vicia faba L.	3	19						
Solanum lycopersicum L.	3	19						
Balanites aegyptiaca (L.) Delile	3	19						
Zygophyllum coccineum L.	3	19						
Suaeda fruticosa Forssk. ex J.F.Gmel.	2	13						
Casuarina equisetifolia L.	2	13						
Senna alexandrina Mill.	2	13						
Gossypium barbadense L.	2	13						
Hibiscus esculentus L.	2	13						
Vitis vinifera L.	2	13						
Caroxylon imbricatum (Forssk.) Moq. var. *imbricatum*	1	6						
Brassica rapa L.	1	6						
Casuarina stricta Miq.	1	6						
Ipomoea carnea Jacq.	1	6						
Cucurbita pepo L.	1	6						
Euphorbia helioscopia L.	1	6						
Rhyncosia minima (L.) DC.	1	6						
Senna didymobtrya (Fresen.) H.S.Irwin & Barneby	1	6						
Senna italica Mill.	1	6						
Mentha longifolia (L.)Huds.	1	6						
Eucalyptus globulus Labill.	1	6						
Musa nana Lour.	1	6						
Boerhavia repens (L.) subsp. *viscosa* (Choisy.) Maire	1	6						
Triticum aestivum L.	1	6						
Rumex dentatus L.	1	6						
Polygonum bellardii All.	1	6						
Tamarix tetragyna Ehrenb.	1	6						
Urtica urens L.	1	6						
Zygophyllum arabicum (L.) Christenh. & Byng.	1	6						
Ammi majus L.			2	18				
Glycine max (L.) Merr.			2	18				
Setaria viridis (L.)P. Beauv.			2	18				
Anethum graveolens L.			1	9				
Coriandrum sativum L.			1	9				
Petrosilinum crispum (Mill.)Fuss.			1	9				
Washingtonia filifera (T.Moore & Mast.)H.Wendl.ex de Bary.			1	9				

Table 3. (Continued)

Species present in one habitat (unique)	HG	PG	RI	VL	HG	PG	RI	VL
	No	f%	No	f%	No	f%	No	f%
Coronopus didymus (L.) SM.			1	9				
Lepidium sativum L.			1	9				
Cyperus laevigatus L.			1	9				
Cassia javanica subsp. *nodosa* (Buch.-Ham ex Roxb.)K.Larsen & S.S Larsen			1	9				
Medicago laciniata (L.) Mill.			1	9				
Vachellia farnesiana (L.) Wight & Arn.			1	9				
Juncus rigidus Desf .			1	9				
Volkameria inermis L.			1	9				
Bombax ceiba L.			1	9				
Melia azedarach L.			1	9				
Plantago major L.			1	9				
Eragrostis tef (Zuccagni.)Trotter.			1	9				
Panicum repens L.			1	9				
Phalaris minor Retz			1	9				
Rumex spinosus L.			1	9				
Rosa chinensis Jacq.			1	9				
Leucophyllum frutescens (Berland.) I.M.Johnst.			1	9				
Senecio glaucus L.					2	25		
Convolvulus fatmensis Kunze.					2	25		
Avena fatua L.					2	25		
Trianthema portulacastrum L.					1	13		
Amaranthus graecizans L.					1	13		
Urospermum picroides (L.) Scop.ex F. W. Schmidt.					1	13		
Spergularia marina (L.) Besser.					1	13		
Trigonella laciniata L.					1	13		
Hibiscus rosa-sinensis L.					1	13		
Polypogon viridis (Gouan) Breistr.					1	13		
Cordia sinensis Lam.							1	25
Lathyrus oleraceus Lam.							1	25
Senna occidentalis (L.) Link.							1	25

Description of cluster groups and ordination of plots

The Public gardens

Group A: *Cynodon dactylon - Melilotus siculus - Alhagi graecorum- Erigeron bonariensis* comprised 3 plots mainly from Kharga oases with Soil analysis of these plots characterized by the lowest content of the majority of studied soil variables, and the highest content of Clay, pH, Na, CO_3, SO_4, PO_4, and organic matter (Table 4). It comprised 53 species, 9 woody perennials (trees or shrubs), 31 annuals, and 22 perennial species. Group A showed the highest species richness (27.33 ± 7.64 species plot $^{-1}$), and Shannon's index (3.27 ± 0.30). Group B: *Dicanthium annulatum - Phoenix dactylifera* included 4 plots with soils exhibited intermediate characters of most of the studied soil variables. It comprised 52 species, of which 16 are woody perennials (trees and shrubs), 30 perennial herbs and 22 annuals. It showed the lowest species richness (19.50 ± 6.56) and Shannon's index (2.91 ± 0.41 species plot $^{-1}$). Group C: *Imperata cylindrica -Ziziphus spina-christi* comprised 4 plots (2 plots of Kharga and 2 plots of Dakhla oasis) with soils had the highest content of most of the studied soil variables e.g. gravels, coarse sand and silt, carbonates, organic matter, but the lowest in fine sand, total soluble salts, electric conductivity, water content and chlorides. It comprised 20 woody perennials, 37 perennial herbs and 32 annuals.

Table (5) gives the eigenvalues of the first two axes (0.553 and 0.409, respectively). The three cluster groups of public gardens (Figure 4) were spread out at 4.478 S.D units along the first DCA axis, expressing the high floristic variations among vegetation groups. The first two DCA axes explained 15.6 and 27.1% of the total variation in species data, respectively.

The home gardens habitat

Group A: *Cynodon dactylon* - *Chenopodiastrum murale*- *Melilotus siculus* comprised 4 plots; 2 from Kharga and two from Dakhla oases, with soils characterized by the lowest content of pH, moisture, organic matter, Ca, Mg, Na, K, fine sand, coarse sand and clay, but the highest in silt (Table 4). It comprised 61 species; 16 woody perennials (trees and shrubs), 16 perennial herbs and 29 annuals. Group B: *Cynodon dactylon* - *Sonchus oleraceus* - *Sorghum halepense* - *Trifolium alexandrinum* comprised of 2 plots from Dakhla Oasis with soils had high contents of gravels, fine and coarse sand, silt, clay, total soluble salts, pH, Ca, Mg, Na and CO_3 , the low contents of SO_4, PO_4,, Cl, K organic matter. It comprised 22 species; 4 woody perennials, 5 perennial herbs and 13 annuals. It showed the highest species richness (25.67 ± 3.22 species plot $^{-1}$) and Shannon's index (3.24 ± 0.13). Group C: *Imperata cylindrica* - *Eruca sativa* - *Chenopodiastrum murale* included 4 plots, three from Dakhla and one from Kharga, with soils had the highest contents of gravels, coarse sand, silt, total soluble salts, water content, pH, Ca, Na and K and the lowest in fine sand, clay, Mg, CO_3 and organic matter. It comprised 53 species; 15 woody perennials, 13 perennial herbs and 25 annuals. Group D: *Ziziphus spina-christi* - *Sesbania sesban* - *Boerhavia diffusa* - *Echinochloa colona* included 4 plots from Dakhla Oasis, with soils had the high contents of gravels, coarse sand, silt, total soluble salts, water content, pH, Ca, Na and K but the lowest contents of moisture, total soluble salts, silt and clay.

Table 4. ANOVA P values of soil variables, species richness (SR) and Shannon's index (H') in the plots representing the groups obtained by cluster analysis in all habitats. WC= water content, pH= soil reaction, TSS= total soluble salts, Cl=chlorides, CO_3= total carbonates, HCO_3= bicarbonates, SO_4= Sulfates, OM= Organic matter, PO_4= Phosphate, CS= Coarse sand and FS= Fine sand. * = $P \leq 0.05$ and ** = $P \leq 0.01$.

Soil variables		Public gardens	Home gardens	Road islands	Vacant lots
Gravels		0.46	0.79	0. 000**	0.02*
CS		0.11	0.82	0.03*	0.75
FS	(%)	0.87	0.75	0.39	0.45
Silt		0.35	0.69	0.04*	0.16
Clay		0.23	0.39	0.01**	0.45
WC		0.45	0.76	0.001**	0.32
OM		0.35	0.71	0.23	0.57
EC	(meq l^{-1})	0.51	0.63	0.59	0.001**
TSS		0.22	0.63	0.67	0.001**
pH		0.49	0.22	0.03*	0.63
Ca		0.36	0.68	0.49	0.17
Mg		0.59	0.69	0.44	0.49
Na		0.19	0.83	0.47	0.28
K		0.55	0.11	0.17	0.26
Cl	(meq l^{-1})	0.39	0.64	0.67	0.21
CO_3		0.31	0.15	0.02*	0.84
SO_4		0.48	0.31	0.21	0.09
PO_4		0.32	0.35	0.39	0.05*
SR		0.34	0. 01**	0.66	0.04*
H'		0.39	0.03*	0.68	0.07

It comprised 71 species, of which 20 woody perennials (trees and shrubs), 17 perennial herbs and 34 annuals were recorded. It showed the lowest species richness (15.67 ± 4.53 species plot $^{-1}$) and Shannon's index (2.71 ± 0.29).

Group E: *Cynodon dactylon - Olea europaea - Coincya tournefortii* included 2 plots from Kharga Oasis with soils had high contents of gravels, fine and coarse sand, silt ,clay , total soluble salts, pH, Ca, Mg, Na and CO_3 the low content of moisture, SO_4, PO_4, Cl, K and organic matter. It comprised 42 species, of which 15 woody perennials (trees and shrubs), 11 perennial herbs and 16 annuals were recorded.

Table (5) gives the eigenvalues of the first two axes (0.531 and 0.376, respectively). The five cluster groups of home gardens (Figure 4) were spread out at 3.744 S.D units along the first DCA axis, expressing the high floristic variations among vegetation groups. The first two DCA axes explained 11.2 and 19.1% of the total variation in species data, respectively.

The road islands habitat

Group A: *Portulaca oleracea - Sonchus oleraceus - Medicago sativa - Tribulus pentandrus* comprised 2 plots of Dakhla Oasis with soils had the highest contents of gravels, coarse sand, water content, pH, carbonates but the lowest in fine sand, silt, clay, EC, TSS, Ca, Mg and SO_4 (Table 4). It comprised 35 species; 3 woody perennials (trees and shrubs), 8 perennial herbs and 24 annuals. This group showed the highest species richness (19 ± 2.83 species plot $^{-1}$) and Shannon's index (2.94 ± 0.15). Group B: *Chenopodiastrum murale - Amaranthus viridis - Dicanthium annulatum* included 2 plots of Kharga and Dakhla Oases with soils rich in contents of gravels, silt, Na, EC and water content, but the lowest contents of fine and coarse sand, Ca, Mg, K and CO_3. It comprised 24 species; 2 woody perennials (trees and shrubs), 4 perennial herbs and 18 annual species. Group C: *Tamarix nilotica - Cenchrus ciliaris - Ziziphus spina-christi - Phragmites australis* comprised 2 plots one form Kharga and the other from Dakhla Oases with soils exhibited intermediate features of most of the studied soil variables. It comprised 25 species; 6 woody perennials, 6 perennial herbs and 13 annuals. Group C showed the lowest species richness (13.0 ± 7.07 species plot $^{-1}$) and Shannon's index (2.48 ± 0.58). Group D: *Convolvulus arvensis - Lysimachia arvensis* var. *caerulea - Lysimachia arvensis* subsp. *arvensis* included 2 plots from Kharga and Dakhla Oases with soils had the lowest contents of gravels, fine and coarse sand, pH, Ca, Mg, K but rich in contents of silt, clay, Na and organic matter. It comprised 39 species; 7 woody perennials (trees and shrubs), 10 perennial herbs and 22 annuals.

Table (5) gives the eigenvalues of the first two axes (0.431 and 0.258, respectively). The two cluster groups of road islands (Figure 4) were spread out at 2.956 S.D units along the first DCA axis, expressing the relatively high floristic variations among vegetation groups. The first two DCA axes explained 25.6 and 40.9% of the total variation in species data, respectively.

The vacant lots habitat

Group A: *Tamarix nilotica - Imperata cylindrica - Malva parviflora* comprised 3 plots from Kharga Oasis with soils rich in contents of fine sand, silt, clay, pH, PO_4 and CO_3, but the lowest contents in gravels, coarse sand, electric conductivity, TSS, Ca, Mg, Na, K, Cl, SO_4 and organic matter (Table 4). It comprised 54 species; 18 woody perennials (trees and shrubs), 17 perennial herbs and 20 annuals. This group showed the highest species richness (24 ± 4.36 species plot $^{-1}$) and Shannon's index (3.17 ± 0.19). Group B: *Alhagi graecorum - Phragmites australis - Prosopis farcta* included 2 plots from Kharga Oasis with soils rich in contents of gravels, coarse sand, electric conductivity, TSS, Ca, Mg, Na, K, Cl, SO_4 and organic matter, but the lowest contents of fine sand, silt, clay, pH, PO_4 and CO_3. It comprised 13 species; 4 woody perennials (trees and shrubs), 4 perennial herbs and 5 annuals. Group B showed the lowest species richness (8.0 ± 5.66 species plot $^{-1}$) and Shannon's index (1.93 ± 0.78).

Table (5) gives the eigenvalues of the first two axes (0.645 and 0.330, respectively). The two cluster groups of road islands (Figure 4) were spread out at 3.104 S.D units along the first DCA axis, expressing the relatively high floristic variations among vegetation groups. The first two DCA axes explained 32.8 and 49.7% of the total variation in species data, respectively.

Table 5. Summary of DCA results for the 4 studied habitats along the first two axes.

Habitats	Public gardens (PG)		Home gardens (HG)		Road islands (RI)		Vacant lots (VL)	
DCA axes	Axis 1	Axis 2	Axis 1	Axis 2	Axis 1	Axis 2	Axis 1	Axis 2
Eigenvalue	0.553	0.409	0.531	0.376	0.431	0.258	0.645	0.330
Length of gradient	4.478	4.422	3.744	3.195	2.956	2.153	3.104	3.097
% Cumulative variance of species data	15.6	27.1	11.2	19.1	25.6	40.9	32.8	49.7

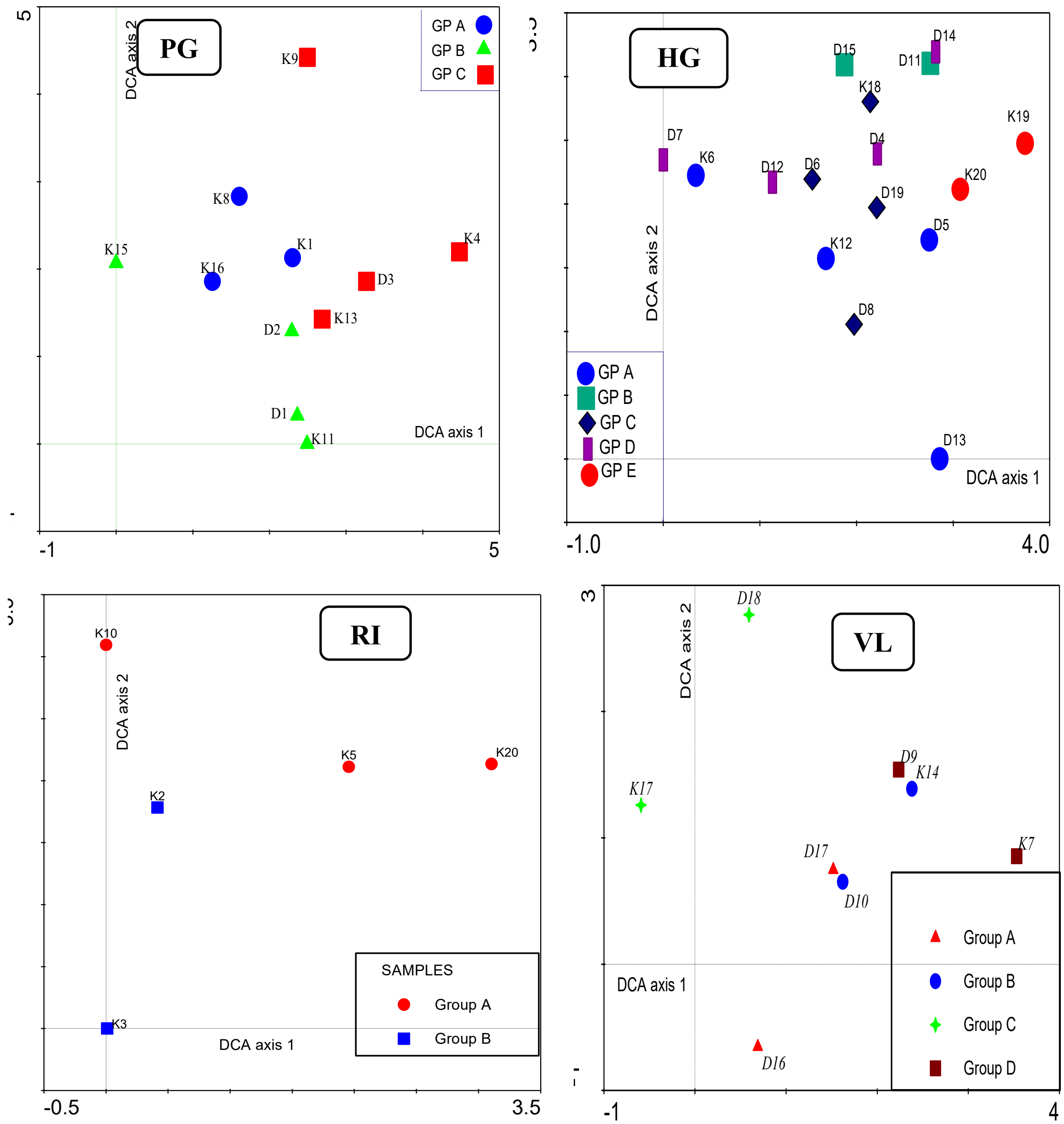

Figure 4. Detrended Correspondence Analysis (DCA) ordination diagram for the plots of the 4 habitats: Public gardens (PG), Home gardens (HG), Road islands (RI) and Vacant lots (VL) on the first two axes, with their cluster groups superimposed.

Soil-vegetation relationships of the habitats

The relationship between vegetation and soil variables was studied using Canonical Correspondence Analysis (CCA). Figure (5) showed the CCA ordination biplots for the studied habitats with their cluster vegetation groups and the examined soil variables. The inter–set correlations resulted from Canonical Correspondence Analysis (CCA) of the examined soil variables in different habitats were displayed in Table (6).

Along with the first CCA axis of the public gardens, the species distribution was positively correlated with K, and negatively correlated with Na. Therefore, this axis can be defined a gradient of K – Na. The second axis was positively correlated with Na, and negatively with Ca. This axis can be defined as Na – Ca gradient (Figure 5, Table 6).

In the home gardens (HG), CCA axis 1 showed significant positive correlation with PO_4 and negatively correlated with silt. Thus, this axis was inferred as PO_4 – silt gradient. Along axis 2, fine sand showed high positive correlation, while pH showed the negative correlation. Therefore, this axis can be defined as a gradient of fine sand – pH (Figure 5, Table 6).

Regarding the vacant lots, the inter-set correlations (Table 6) showed that soil texture especially gravels had strong positive correlation (r=0.96), and clay had the highest negative correlation (r=-0.94) along CCA axis 1. Therefore, this axis can be defined as gravels – clay gradient (Figure 5). In the meantime, CCA axis 2 indicated high positive correlation with silt, and negative correlation with K. Therefore, this axis can be inferred as silt – K gradient.

The CCA axes of the interest correlations (Table 6) of the road islands indicated that the first CCA axis was high positively correlated (r=0.79) with pH, and strongly negatively correlated (r=-0.87) with Na. So, this axis can be defined as pH – Na gradient. Along axis 2, soil texture affected the distribution of species where fine sand had high positive correlation (r=0.65), and gravels had the strongest negative correlation (r=-0.81). Thus, this axis can be inferred as a gradient of fine sand.

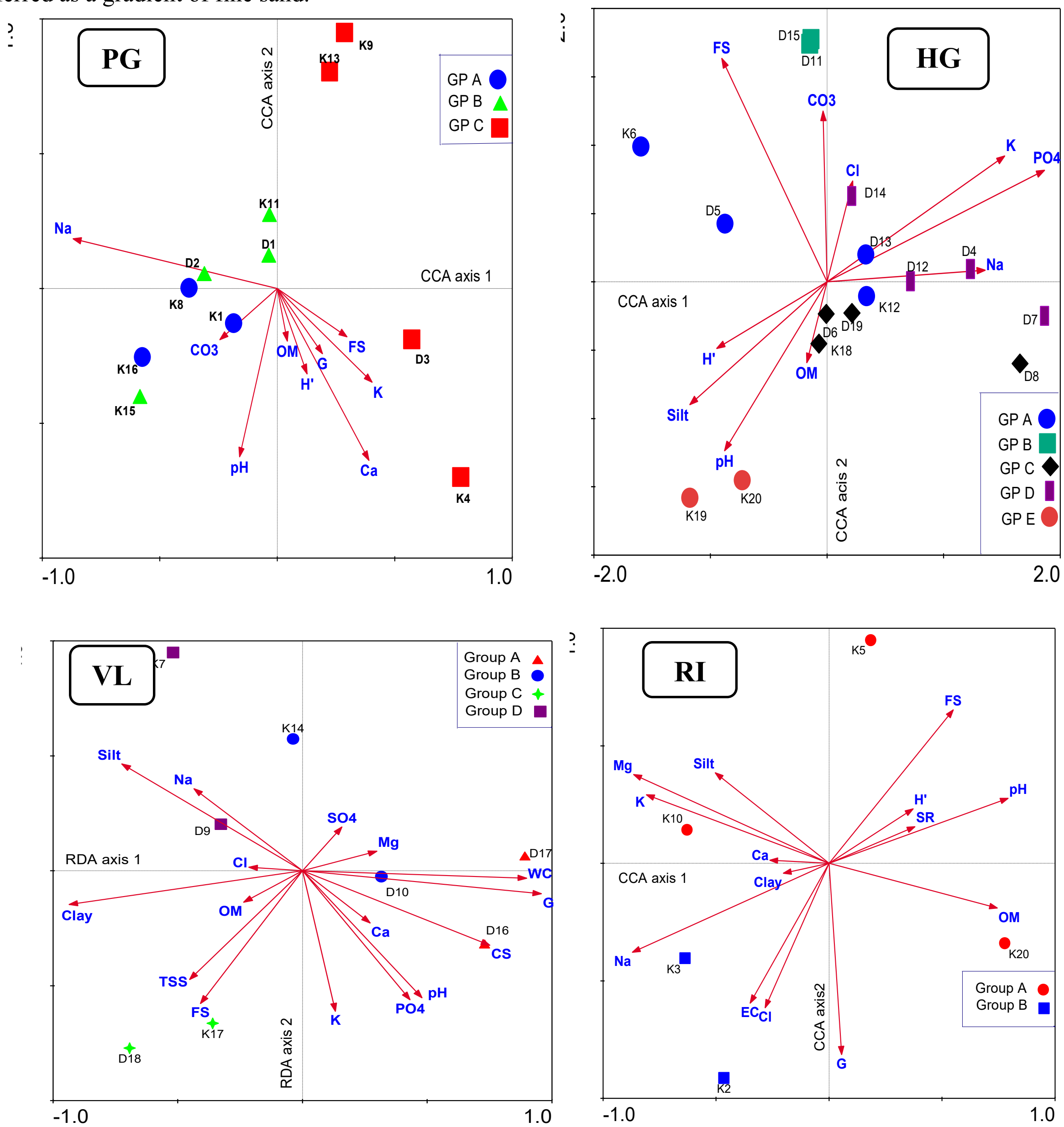

Figure 5. CCA biplots along axes 1 and 2 showing the distribution of the plots of the four habitats, together with their cluster groups and soil variables. PG=Public gardens, HG=Home gardens, RI=Road Island and VL=Vacant lots.

Table 6. The results of inter–set correlation of soil variables along the first two axes of CCA, together with eigenvalues and species–environment correlation coefficients in the four habitats of Kharga and Dakhla Oases. CS=Coarse sand and FS= Fine sand, WC=Water content, EC= Electric conductivity, TSS=Total soluble salts, OM=Organic matter, SR= Species richness, H'= Shannon-Wiener index, NI= Not included (high inflation factor).

Habitats		**PG**		**HG**		**VL**		**RI**	
Axes		**Ax_1**	**Ax_2**	**Ax_1**	**Ax_2**	**Ax_1**	**Ax_2**	**Ax_1**	**Ax_2**
Eigenvalues		0.55	0.45	0.48	0.44	0.65	0.58	0.23	0.19
Species-environment correlations		0.98	0.99	0.99	0.99	0.98	0.96	0.98	0.97
Gravels		0.19	-0.24	NI	NI	0.96	-0.10	0.05	-0.81
CS		NI	NI	NI	NI	0.75	-0.32	NI	NI
FS	(%)	0.30	-0.18	-0.32	0.58	-0.41	-0.58	0.55	0.65
Silt		NI	NI	-0.42	-0.32	-0.72	0.46	-0.50	0.39
Clay		NI	NI	NI	NI	-0.94	-0.15	-0.20	-0.04
WC		NI	NI	NI	NI	0.89	-0.03	NI	NI
OM		0.04	-0.20	-0.06	-0.21	-0.24	-0.14	0.75	-0.19
EC		NI	NI	NI	NI	NI	NI	-0.35	-0.59
TSS		NI	NI	NI	NI	-0.45	-0.47	NI	NI
pH		-0.16	-0.62	-0.32	-0.45	0.48	-0.55	0.79	0.28
Ca		0.38	-0.64	NI	NI	0.27	-0.23	-0.26	0.01
Mg		NI	NI	NI	NI	0.29	0.08	-0.86	0.38
Na	(meq l^{-1})	-0.87	0.18	0.49	0.03	-0.44	0.36	-0.87	-0.38
K		0.40	-0.35	0.55	0.33	0.13	-0.61	-0.80	0.29
Cl		NI	NI	0.08	0.27	-0.22	0.02	-0.28	-0.61
SO_4		NI	NI	NI	NI	0.16	0.19	NI	NI
PO_4		NI	NI	0.67	0.29	0.43	-0.56	NI	NI
CO_3		-0.24	-0.19	-0.01	0.45	NI	NI	NI	NI
H'		0.13	-0.32	-0.34	-0.18	NI	NI	0.37	0.23

Discussion

The study of plant distribution patterns in urbanized habitats of Kharga and Dakhla Oases in the Western Desert of Egypt provides valuable insights into the ecological dynamics of vegetation in arid environments. The findings highlight the significant influence of human activities, such as urbanization and agricultural practices, on species composition and distribution. The results also underscore the importance of soil characteristics in shaping vegetation patterns, particularly in managed and disturbed habitats.

Urbanization and Plant Diversity

Urban environments are known to support diverse plant species, ranging from naturally occurring flora in disturbed areas to cultivated ornamental plants in managed spaces [56]. In this study, four main habitat types were identified: home gardens (HG), public gardens (PG), road islands (RI), and vacant lots (VL). Each habitat exhibited distinct species compositions, reflecting the varying degrees of human intervention and environmental conditions.

Managed habitats, particularly home gardens and public gardens, exhibited the highest species richness. Home gardens, with 132 species, were characterized by a mix of fruit trees, native xerophytes, and cultivated herbs. Public gardens, with 112 species, supported ornamental plants and wetland species. These findings align with previous studies that have shown that managed urban habitats often harbor higher plant diversity due to the intentional introduction of ornamental and cultivated species [42, 67]. In contrast, disturbed habitats such as road islands and vacant lots were dominated by weeds and xerophytic species, adapted to harsh, unmanaged conditions. Road islands had 71 species, while vacant lots had only 58 species, reflecting the challenging environmental conditions of these areas.

Soil-Vegetation Relationships

The study revealed significant differences in soil properties across the four habitat types, which in turn influenced species distribution. Soil variables such as electrical conductivity, total soluble salts, and chloride content were particularly influential in shaping species distribution in saline environments, while organic matter and clay content played key roles in managed habitats. These findings are consistent with previous research that has highlighted the importance of soil properties in determining plant community composition in arid regions [4].

For instance, in public gardens, soil analysis of plots dominated by *Cynodon dactylon* - *Melilotus siculus* - *Alhagi graecorum* - *Erigeron bonariensis* (Group A) showed the lowest content of most soil variables but the highest content of clay, pH, sodium, carbonates, sulfates, phosphates, and organic matter. This group exhibited the highest species richness and Shannon's index, indicating a diverse plant community adapted to these specific soil conditions. In contrast, plots dominated by *Dicanthium annulatum* - *Phoenix dactylifera* (Group B) in public gardens had intermediate soil characteristics and lower species richness, suggesting that soil properties significantly influence plant diversity.

Similarly, in home gardens, soil properties varied significantly among the different vegetation groups. For example, plots dominated by *Cynodon dactylon* - *Olea europaea* - *Coincya tournefortii* (Group E) had high content of gravels, fine and coarse sand, silt, clay, total soluble salts, pH, calcium, magnesium, sodium, and carbonates, but low moisture, sulfates, phosphates, chlorides, potassium, and organic matter. This group had moderate species richness, indicating that even within managed habitats; soil heterogeneity can lead to variations in plant diversity.

Synanthropic Vegetation and Human Influence

The study also highlighted the role of synanthropic vegetation, which is strongly influenced by human activity. Synanthropic plants, including weeds and ruderal species, were prevalent in disturbed habitats such as road islands and vacant lots. These species are well-adapted to urban environments and often thrive in areas with high levels of disturbance [38, 47]. In this study, weed species had the highest contribution (40%) in road islands, while ornamentals exhibited a more uniform distribution across habitats, ranging from 8.9% in vacant lots to 16.2% in public gardens.

The presence of synanthropic vegetation in urban habitats underscores the impact of human activities on plant distribution. Urbanization often leads to habitat fragmentation, pollution, and physical disturbances, which can restrict the growth of native flora and favor the establishment of invasive and ruderal species [25, 42]. In the context of Kharga and Dakhla Oases, the expansion of urban areas and agricultural practices has likely contributed to the spread of synanthropic species, particularly in disturbed habitats.

Implications for Urban Planning and Conservation

The findings of this study have important implications for urban planning and conservation in arid regions. The high species richness observed in managed habitats such as home gardens and public gardens suggests that these areas can serve as important refuges for plant diversity in urban environments. However, the dominance of synanthropic species in disturbed habitats highlights the need for effective management strategies to control the spread of invasive species and preserve native flora.

Urban planning efforts should consider the ecological dynamics of vegetation and the role of soil properties in shaping plant communities. For example, the introduction of native and drought-tolerant species in public gardens and home gardens could enhance biodiversity and reduce the need for irrigation in arid environments. Additionally, the restoration of disturbed habitats, such as vacant lots and road islands, could involve the reintroduction of native species and the improvement of soil conditions to support their growth.

Conclusions

In conclusion, this study provides a comprehensive analysis of plant distribution patterns in urbanized habitats of Kharga and Dakhla Oases. The results highlight the significant influence of human activities and soil properties on species composition and distribution. Managed habitats, such as home gardens and public gardens, exhibited the highest species richness, while disturbed habitats were dominated by synanthropic species adapted to harsh conditions. These findings underscore the importance of considering ecological dynamics and soil characteristics in urban planning and conservation efforts in arid regions. Future research should focus on long-term monitoring of vegetation changes in response to urbanization and the development of sustainable management practices to enhance biodiversity in urban environments.

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