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Ecological insights and floristic diversity pattern of the reclaimed desert agroecosystems in Egypt's Western Desert: A case study of El-Keram integrated farm system

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Agroecosystems are modified natural systems designed to produce food and fiber, integrating ecosystem services like soil fertility enhancement, water provisioning, and pollination. In Egypt, land reclamation projects in the Western Desert aim to alleviate overpopulation pressures, enhance food security, and transform arid landscapes into productive agricultural areas. This study investigates the floristic diversity and ecological patterns of reclaimed agroecosystems in the El-Beheira Governorate, a key region for agricultural expansion. Fieldwork was conducted in 2022, surveying 29 stands, including natural and reclaimed habitats, to document plant species composition, life forms, habitats, and chorological types. Diversity patterns were analyzed using alpha diversity indices, while vegetation communities were classified using TWINSPAN and DECORANA. Soil samples from each stand were analyzed for texture, nutrients, and salinity to identify edaphic drivers of diversity. The results revealed 111 plant species spanning multiple life forms and geographic origins, reflecting the interaction of natural desert vegetation with reclaimed agricultural habitats. Canonical Correspondence Analysis (CCA) highlighted significant relationships between environmental variables and vegetation communities, demonstrating the influence of soil salinity, nutrient availability, and land management practices on floristic diversity. The findings underscore the importance of sustainable agricultural practices in maintaining biodiversity and ecosystem functionality in reclaimed agroecosystems. Recommendations for biodiversity conservation and habitat management include minimizing agrochemical inputs, enhancing soil fertility naturally, and integrating natural vegetation patches into agricultural landscapes. This study provides valuable insights into the ecological dynamics of reclaimed desert agroecosystems, contributing to efforts aimed at balancing agricultural productivity with biodiversity conservation in arid regions.

Keywords: diversity pattern; reclaimed desert; vegetation communities; alien species; vegetation changes; sustainable farming practices

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INTRODUCTION

Agroecosystems are natural ecosystems that have been modified to produce food and fiber (Vandermeer, 2011; Hodgson, 2012; Altieri & Nicholls, 2018; Okeke et al., 2022). These systems provide and rely on ecosystem services, particularly those termed "services to agriculture". These support the production of harvestable goods including enhancement of soil structure and fertility, cycling of nutrient, provisioning of water, pest and erosion control, and pollination (Zhang et al., 2007; Liu et al., 2020; Randall and Smith, 2020). Conversely, ecological processes that hinder agricultural production, such as pest damage, competition for water, and pollination issues, are considered "disservices to agriculture" (Zhang et al., 2007). Management practices within agricultural ecosystems influence the flow of both ecosystem services and disservices from production landscapes to surrounding areas. Services provided by agriculture include provisioning services, carbon sequestration, soil conservation, cultural and aesthetic benefits, and habitat provision. On the other hand, disservices often involve habitat degradation, soil erosion, and water quality deterioration, typically resulting from agricultural management practices (Garbach et al., 2014).

While agroecosystems retain many characteristics of natural ecosystems, they are distinct from a toxicological perspective due to the frequent presence of agrochemicals, including pesticides, fertilizers, and plant growth regulators. The nature and extent of agrochemical contamination vary significantly depending on the type of crops and livestock involved (Hodgson, 2012). Agroecosystems are inherently nutrient-leaky systems requiring careful management to minimize losses. Nutrient leakage often occurs from exposed soil between crops and during fallow periods. Modern agriculture relies heavily on external inputs such as fertilizers, pesticides, and machinery to replenish lost nutrients and sustain production. However, these inputs increase the carbon footprint of agroecosystems. While some agroecosystems achieve high crop yields per hectare with increased inputs, lower-input systems like those in India highlight the need for more efficient and sustainable practices. Heavy metals are among the most hazardous toxicants in agroecosystems, and their persistence and stability prevent degradation, leading to bioaccumulation in plants, animals, and humans through soil, water, and food chains (Nagajyoti et al., 2010; Tutic et al., 2015).

Inappropriate land use results in inefficient resource exploitation, land degradation, poverty, and social problems (Rossiter, 1996). Land use and land cover data are critical for addressing hazards, uncontrolled development, environmental degradation, loss of prime agricultural land, habitat destruction, changes in biotic communities' composition and biodiversity loss (Anderson and Inouye, 2001; El-Fahar & Sheded, 2002). Land evaluation, as defined by the FAO (1985), involves assessing land performance for specific uses, using soil and site properties as fundamental inputs (Beek, 1978; Van Diepen et al., 1991).

In Egypt, particularly in Nile Delta, rapid population growth exerts immense pressure on the agricultural sector to meet increasing food demands (Negm et al., 2016). Farmers often resort to using wastewater or low-quality freshwater for irrigation due to limited water resources essential for agricultural expansion in this over-exhausted region. Consequently, the use of low-quality irrigation water has led to elevated levels of heavy metals in agricultural soils (Balkhair & Ashraf, 2016). Such practices not only impact food quality and safety but also pose significant risks to natural ecosystems and eventually to human health (Gall et al., 2015). The government initiatives focus on establishing new settlements and land reclamation projects to address overpopulation and food security challenges. Policies aimed at achieving food self-sufficiency have prioritized the horizontal expansion of cultivated areas, necessitating the evaluation and classification of soils based on their agricultural productivity.

Reclamation projects have been ongoing in northern Egypt several decades particularly as early as 1980s, focusing on transforming desert lands into productive agricultural areas (Radwan, 2019). Reclaimed agricultural lands dominate the landscape, particularly in the eastern side closer to the Nile Delta (Alary et al., 2018; Elsharkawy et al., 2022). Additionally, the southwestern fringes of the Nile Delta represent a promising area for land reclamation due to favorable soil conditions, groundwater availability, and proximity to Cairo, Alexandria, and the northwestern coast. El-Beheira Governorate had significant share in terms of agricultural development and reclamation of projects (Alary et al., 2018; Radwan, 2019). In these areas where the desert hinterland exists, the natural vegetation consists mainly of sparse desert shrubs and grasses adapted to arid conditions.

Understanding the dynamics of plant communities and their relationship with environmental and soil parameters is crucial for biodiversity conservation and habitat management. This study explores the floristic composition, vegetation communities, and diversity patterns in heterogeneous landscape agroecosystems. The research evaluates the pattern of floristic composition within of the reclaimed desert agroecosystem in the Western Desert of Egypt. The main objectives include (1) document and analyze the taxonomic composition of plant species in the study area, including their life forms, habitats, geographical distributions, and chorological types; (2) identifying species diversity pattern across the different habitats and vegetation groups and investigate the ecological and edaphic drivers behind these patterns; and (3) providing insights into biodiversity conservation and sustainable habitat management based on the interactions between vegetation, habitats, and soil properties.

MATERIALS AND METHODS

Study area

The study area is located west of the Nile Delta, in the southeastern part of El-Beheira Governorate, extending into the adjacent desert hinterland (Fig. 1). This region features a mix of natural and human-modified agroecosystems. The topography is generally flat to slightly undulating, with elevations gradually increasing westward into the desert. The area transitions from the fertile alluvial plains of the Nile Delta to the arid desert landscapes (Zahran & Willis, 2008). In the eastern parts near the Western Desert, the landscape is characterized by desert pavements with rocky or sandy surfaces, and soils progressively become more arid, sandy, and less fertile toward the western and southern desert hinterlands. The region experiences an arid desert climate under the Köppen climate classification (Peel et al., 2007). Summers are hot and dry, with temperatures often exceeding 40°C, while winters are mild, with temperatures ranging from 8°C to 20°C. Annual rainfall is minimal, typically less than 100 mm, and occurs mostly during winter. High evaporation rates, low relative humidity, and strong winds further define the region's climate (Alary et al., 2018).

The primary habitats include reclaimed agricultural lands, natural desert patches, scattered salt flats, and saline areas (Bakr & Bahnassy, 2019). Reclaimed agricultural lands dominate the eastern side near the Nile Delta (Alary et al., 2018; Elsharkawy et al., 2022). In contrast, the western and southern areas are characterized by sparse desert vegetation, consisting mainly of shrubs and grasses adapted to arid conditions (Figure 1).

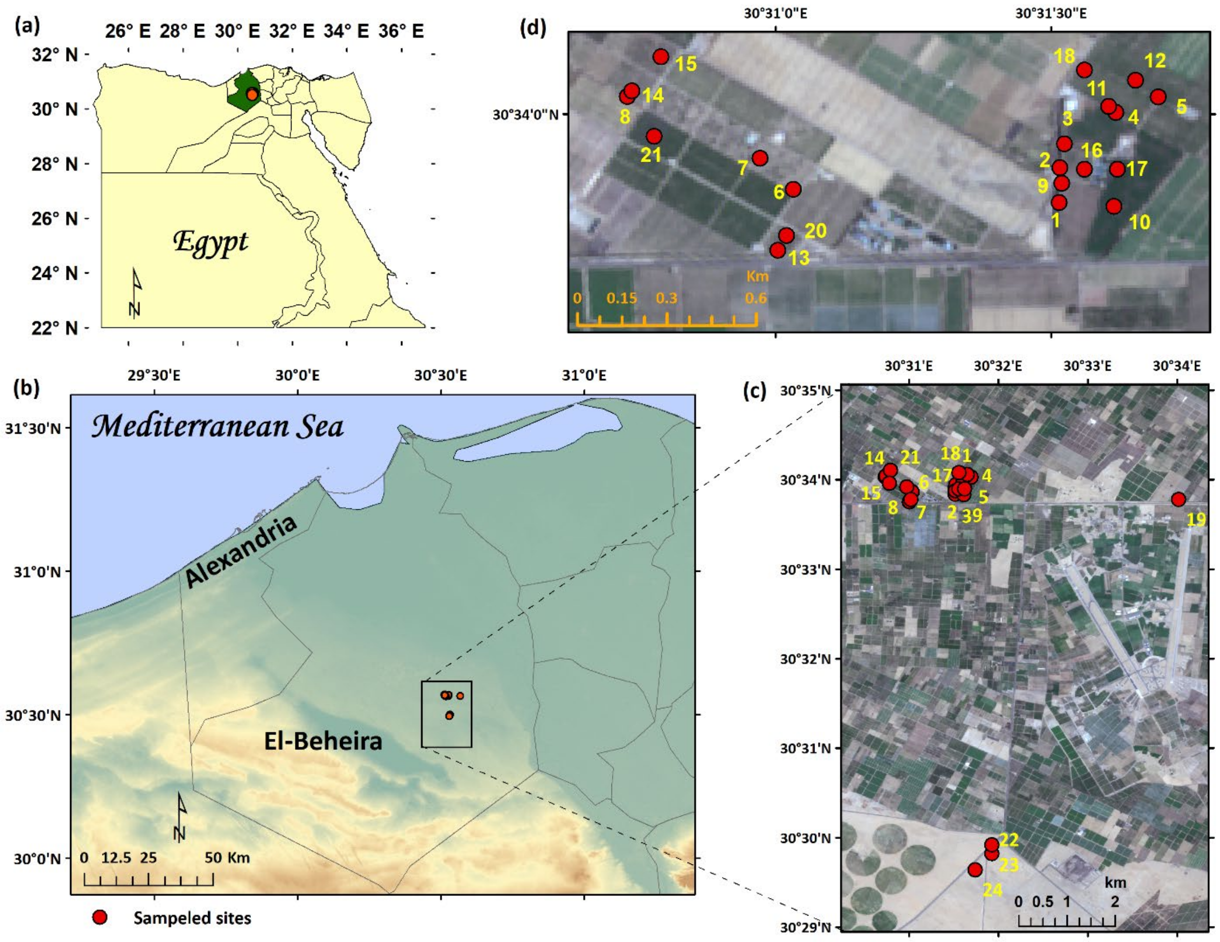


Figure 1. Location of the study area. (a) Map of Egypt administrative boundaries showing location of El-Beheira governorate in which study area is located. (b) Area to the west of the Nile Delta showing location the sampled area at the southeastern part of El-Beheira governorate. (c) Subset of Sentinel 2 satellite image that was acquired on 31/5/2022 showing the distribution of the sampled sites within the study area which includes El-Keram Farm and the desert hinterland. (d) Enlarged part of the Sentinel 2 satellite showing the distribution of sampled sites within El-Keram Farm.

Newly created habitats, such as man-made ponds and canals, have emerged due to ongoing reclamation projects, which began in northern Egypt as early as the 1980s. These projects aim to transform desert land into productive agricultural areas (Radwan, 2019). El-Beheira Governorate has played a significant role in agricultural development and reclamation efforts (Alary et al., 2018; Radwan, 2019).

El-Keram Farm, one of the most prominent farms in El-Beheira Governorate, is in Badr Center near Sadat City. Spanning 500 feddans, the farm cultivates a variety of crops, including fruit trees (Mango, Peach, Apricot, Citrus such as summer Orange and Mandarin, and Date palms like Barhi and other local varieties) and seasonal crops (Corn, Alfalfa, Beans, and Soybeans). Agricultural activities rely primarily on groundwater for irrigation. Drip irrigation systems are widely used for fruit trees, while sprinklers irrigate seasonal crops, maximizing water efficiency. Additionally, water from integrated fish farming systems, which raise tilapia and catfish, is recycled to irrigate alfalfa fields. This process enriches the soil with organic fertilizers from fish farm effluent, transforming sandy soil into fertile land. Integrated systems are considered highly cost-effective in Egypt (Sadek, 2011). These systems provide several benefits:

- They enable water storage, which is critical as obtaining water from irrigation districts can be time-consuming.
- They support pressurized irrigation systems such as drip and sprinkler irrigation.

- Fish waste serves as fertilizer, with effluent water used to irrigate crops such as vegetables, fruits, and wheat.
- Productivity and income are enhanced by utilizing the same volume of water for multiple purposes, including fish farming, crop cultivation, and livestock production.

The integrated systems at El-Keram Farm are meticulously designed so that each output serves as input for the next stage, as described by El-Guindy (2006). The farm integrates two annual fish crops with arable farming, livestock, and biogas production. Each year, the farm produces 100 tons of tilapia and 100 tons of catfish. Effluent water from fish farming irrigates 7,800 tons of Egyptian clover annually, providing fodder for 1,300 sheep. Sheep manure is then used to produce biogas, which heats water for the tilapia hatcheries (Figure 2 and Table 1).

Sampling and data collection

In the spring of 2022, 26 stands were selected within El Keram farm, along with 3 additional stands outside the farm as a control group (Fig. 1). At each stand, the following data were collected: (a) geographic coordinates (latitude/longitude) using a handheld Garmin GPSMAP® 64s, (b) a list of natural weed species, and (c) identification of the most dominant species following the method described by Müller-Dombois & Ellenberg (1974). The collected data was organized into a raw table listing the species observed in the sampled stands. Herbarium specimens were prepared and identified using the nomenclature of Boulos (1999–2005, 2009). Voucher specimens of the recorded species were deposited in the author's collection (Herbarium of The Botanic Garden of Alexandria University, Heneidy et al. Collection) and the Herbarium of Alexandria University, Faculty of Science.

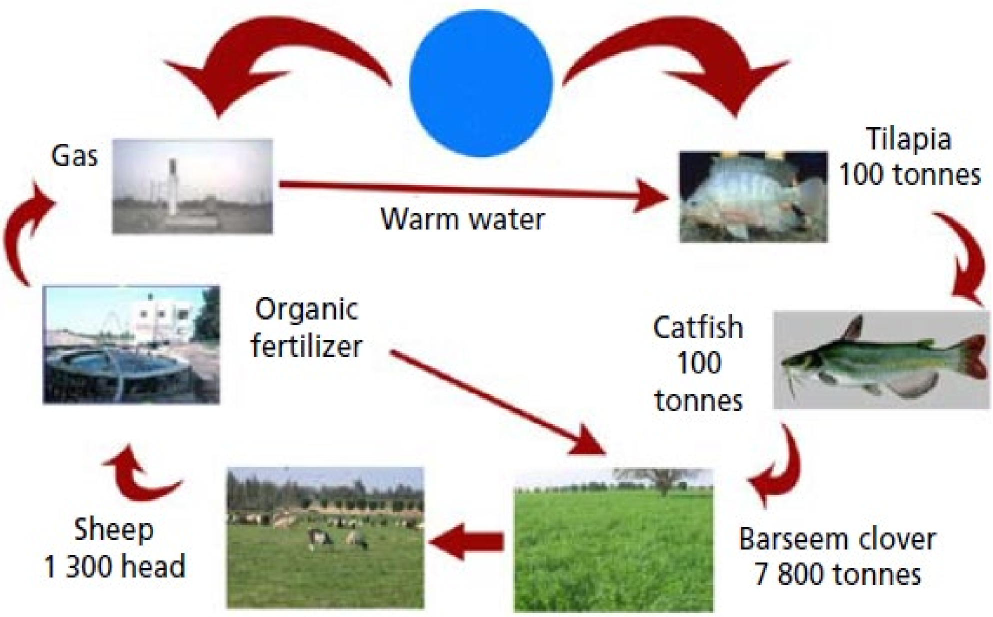


Figure 2. El-Keram integrated agroecosystems in the Egyptian desert, only one source of water (After El-Guindy, 2006).

Table 1. Comparison between the non-integrated agriculture system and El-Keram agriculture integration project system (fish/clover/sheep/organic-fertilizer/biogas) in the Egyptian desert. Source: (Sadek, 2011).

Item	Non-integrated agriculture systems	El-Keram integrated system
Water units	3	1
Talipia	100 tons	100 tons
Catfish	100 tons	100 tons
Clover	4500 tons	7800 tons
Sheep (head)	Nil	Yes
Waste	Nil	Yes
Irrigated land (hectars)	42	55
Water conservation	0%	67%

Vegetation analysis

The life forms of recorded species were classified according to Raunkiaer's system into the following categories: Phanerophytes, Chamaephytes, Geo-Helophytes, Hemicryptophytes, Parasites, and Therophytes (Raunkiaer, 1937). The relative contribution of each life form to the flora was used to construct a biological spectrum, providing insight into the ecological relationships and climatic conditions of the study area. The global geographical distribution of the recorded taxa was documented based on the classifications of Zohary (1966, 1972) and Feinbrun-Dothan (1977, 1978).

Diversity indices

Diversity was assessed as a function of species richness and evenness of individual distribution across species (Stirling and Wilsey, 2001). Five commonly used alpha diversity indices, as described by Magurran (2004), were calculated: 1) Richness = the number of species recorded at each site; 2) Shannon's diversity index (H') = $-\sum p_i \ln p_i$, where p_i is the proportional abundance of the i_{th} species; 3) Simpson's index of dominance (D) = $\sum p_i^2$; 4) Hill's number 1(N1) = exponential Shannon's index = $e^{H'}$, and 5) Shannon evenness index (E1) = $H'/H_{max} = H'/\ln S$, where S is the number of species.

Soil analysis

Composite soil samples (~2 kg) were collected from each stand, stored in plastic bags, and transported to the laboratory within 24 hours. Samples were air-dried, ground to break aggregates, and sieved through a 2 mm mesh for further analysis. Soil texture and particle size distribution were determined using the Bouyoucos hydrometer method, and saturation percentage (SP) was calculated (Allen et al., 1986). Organic matter (OM) content was measured using the Walkley–Black method. Concentrations of soluble soil cations (Ca^{2+}, Mg^{2+}, K^+, Na^+) and anions (SO_4^{2-}, HCO_3^-, Cl^-) were measured in meq/L, alongside available micronutrients and macronutrients (Fe, Cu, Mn, Zn, N, and P) in ppm. The sodium adsorption ratio (SAR) was calculated as SAR=Na/(0.5×(Ca+Mg))SAR=\sqrt {\text {Na}}/(0.5\times (\text{Ca}+\text{Mg})) SAR=Na/(0.5×(Ca+Mg)). Soil salinity, total dissolved solids (TDS), and pH were determined using soil extracts (Allen et al., 1986). Salinity (EC) and TDS were measured with a conductivity meter, while pH was assessed with a pH meter (Jenway 3020, Cole-Parmer, Staffordshire, UK). Titration was used to measure Ca^{2+}, Mg^{2+}, HCO_3^-, and Cl^-. Flame photometry was employed to determine Na^+ and K^+ concentrations, and SO_4^{2-} was analyzed spectrophotometrically. Micronutrient concentrations (Fe, Zn, Mn, Cu) were determined by atomic absorption spectroscopy, and available P was measured via flame photometry. Calcium carbonate ($CaCO_3$) content was determined with Bernard's calcimeter, and nitrogen concentration was measured using the Kjeldahl method (Allen et al., 1986).

Data analysis

Two-way indicator species analysis (TWINSPAN) and detrended correspondence analysis (DECORANA) were employed to classify vegetation cover data for the 111 species recorded across 29 stands, identifying plant communities in the study area (Hill, 1979a, 1979b; Gauch & Whittaker, 1981). Linear correlation coefficients were calculated to evaluate the relationships between diversity indices and environmental variables. Normality of the data was checked using Shapiro–Wilk's W test, and homogeneity of variance was assessed with Levene's test. Data were log-transformed, when necessary, before applying one-way analysis of variance (ANOVA) to detect significant differences in diversity indices among six vegetation groups. A Student's t-test was used to compare diversity indices between two habitat types (train/tram). Canonical correspondence analysis (CCA) was performed to examine the relationship between environmental variables and ecological groups, based on direct gradient changes (TerBraak & Looman, 1987; Palmer, 1993).

RESULTS

Floristic composition

The recorded taxa in the study area, as well as their national geographical distribution, life forms, habitats, chorological types, and vegetation groups are listed in Table 2. The total number of recorded taxa was 111, belonging to 86 genera and 29 families. About 43.6% of the recorded taxa (44 species) were perennials, while 59.5% (66 species) were annual and only one species is biennial. In total 93 species (36 perennials and 57 therophytes) were native flora, of which 62 species were recorded as weeds (15 perennials and 47 therophytes), and 18 species (16.2%) were assessed as alien (6 casual, 10 naturalized and 2 invasive alien species (*Bassia indica* and *Persicaria decipiens*). The five richest species contributed 56.8% (63 species) of the total number of species (Table 3, Figure 3). On the other hand, 11 species were common, and recorded in ≥ 50% of the sampled stands: *Conyza bonariensis* (90.0%), *Cynodon*

Table 2. Number of stands, species richness, habitat distribution (CB = canal banks ; MD = Medicago fields; LO = Limon-Orange; AP = Apricot farms; MG = Mango farms; PR=; NT = Natural habitat), and dominant species for detected vegetation groups.

VG	No of Stands	No. species	Habitats							First dominant	Second dominant
			CB	MD	LO	AP	MG	PR	NT		
I	3	36							100	*Artemisia monosperma*	*Zilla spinosa*
II	8	37			13	25	25	38		*Chenopodium murale*	*Conyza bonariensis*
III	10	57			70		30			*Conyza bonariensis*	*Sonchus oleraceus*
IV	3	58	100							*Cynodon dactylon*	*Sisymbrium irio*
V	6	49		100						*Rumex dentatus*	*Conyza bonariensis*

dactylon (73.3%), *Senecio glaucus subsp. coronopifolius* (73.3%), *Solanum nigrum* (73.3%), *Chenopodium murale* (70.0%), *Cynanchum acutum* (70.0%), *Sonchus oleraceus* (70.0%), *Brassica tournforthii* (63.3%), *Malva parviflora* (60.0%), *Sisymbrium irio* (60.0%) and *Polypogon monsepliensis* (50.0%).

The canal banks habitat contained the highest number of species (58 species = 52.25% of the total recorded taxa, 72.41% weeds), followed by the Limon-Orange farms (50 species = 45.05%, 74% weeds), and Medicago fields (49 species = 44.14%, 71.43%), while Apricot farms contained the lowest number of species (20 species = 18.02%, 80% weeds) (Table 2). Regarding the life form spectra of the recorded flora, therophytes made the highest contribution (66.59% of the total species), followed by hemicryptophytes (13.12%), phanerophytes and chamaephytes (12.11% each), and geophytes (7.6%) (Fig. 4). In the local geographical distribution, 86.49% of the recorded taxa were on the Mediterranean coast, followed by the Nile region (79.28%), Sinai (74.77%), Egyptian deserts (72.97%), and Oasis (62.16%). Regarding the global phytogeographical distribution, the bi-regional elements were the most prevalent (36 species = 32.43%), followed by pluri-regionals (31 species = 27.93%), and mono-regionals (30 species= 27.03%), then Cosmopolitan (14 species = 12.61%) (Figure 5). On the other hand, 52 species belonged to Mediterranean elements, and of these 6 species were mono-regionals; 44 species were Irano-Turanian, of which no one was mono-regional; 32 species were Saharo-Arabian, of which 9 were mono-regionals, and 21 species were European elements (Figure 6).

Plant communities and diversity indices

The application of TWINSPAN to the cover estimates of 111 species recorded in 29 stands led to the recognition of 5 vegetation groups at the third level of classification (Figure 7). The application of DECORANA on the same set of data indicates reasonable segregation among these groups along the ordination axes 1 and 2 (Fig. 8). The vegetation groups are named after the species with the highest percentage (first dominant species), as follows (Table 2): I— *Artemisia monosperma* community represents the natural habitat with 36 species. The most dominant species are *Artemisia monosperma*, *Zilla spinosa*, *Schismus barbatus*, *Deverra tortuosa*, *Cynanchum acutum*, *Cornulaca monacantha*, and *Bassia muricata*; II— *Chenopodium murale* community represents all different habitats with 37 species. The most dominant species are: *Chenopodium murale, Conyza bonariensis, Cynanchum acutum, Senecio glaucus* subsp. *coronopifolius,* and *Sonchus oleraceus*; III— *Conyza bonariensis* community represents Limon-Orange habitat (70% of its stands) with 57 species. The most dominant species are: *Conyza bonariensis, Sonchus oleraceus, Solanum nigrum, Senecio glaucus* subsp. *coronopifolius, Conyza bonariensis*, *Brassica tournforthii*, *Polypogon monsepliensis* and *Sisymbrium irio*; IV— *Cynodon dactylon* community represents canal banks habitat with 58 species. The most dominant species are: *Cynodon dactylon, Solanum nigrum, Sisymbrium irio, Rumex dentatus, Melilotus indicus, Malva parviflora, Emex spinosa, Conyza bonariensis* and *Bromus cathariticus*; V— *Rumex dentatus* community represents the Alfa Alfa fields with 49 species. The most dominant species are: *Rumex dentatus, Conyza bonariensis, Bromus cathariticus, Cenchrus ciliaris, Cynodon dactylon, Emex spinosa, Malva parviflora* and *Sisymbrium irio* (Table 3).

Diversity indices

Seven of the more popular indices of alpha diversity were applied to the studied sites. The effect of habitat type on species diversity (richness, dominance, diversity and evenness) was considered and evaluated. The species diversity of different classified vegetation groups was also estimated (Table 4). Variations in the results of species diversity indicate the highly significant effects of habitat type on species diversity. This observation is borne out by indices that incorporate information on proportional abundances

Table 3. Species composition and percentage of occurrence (P) across habitats and vegetation groups. The represented habitats CB = canal banks ; MD = Medicago fields; LO = Limon-Orange; AP = Apricot farms; MG = Mango farms; PR=; NT = Natural habitat.

Species	Habitats							Vegetation groups					P
	CB	MD	LO	AP	MG	PR	NT	I	II	III	IV	V	(%)
Aegilops ktschyi							33	33					3.3
Aizoon canariense							33	33					3.3
Alhagi graecorum			13				33	33		10			6.7
Amaranthus graecizans	33										33		3.3
Amaranthus hybridus	67	17	25	100		33			50	10	67	17	26.7
Amaranthus lividus	33		13			67			25	10	33		13.3
Amaranthus retroflexus		17										17	3.3
Amaranthus viridis	67	17		50					13		67	17	13.3
Ammi majus	33										33		3.3
Anagallis arvensis	33		13							10	33		6.7
Artemisia monosperma							100	100					10.0
Avena barbata	33	50									33	50	13.3
Avena fatua	33	67	13							10	33	67	20.0
Bassia indica	67	17	25	50	60		67	67	25	40	67	17	36.7
Bassia muricata			38	50	100		100	100	38	60			40.0
Bidens pillosa	67	17			20					10	67	17	13.3
Brachypodium distachyon	33		25							20	33		10.0
Brassica tournforthii	67	33	75	50	100	67	33	33	75	80	67	33	63.3
Bromus cathariticus	100	83	13		20					20	100	83	33.3
Calligonum comosum							67	67					6.7
Capsella bursa-pastoris	33	33									33	33	10.0
Caroxylon tetrandrum							67	67					6.7
Caroxylon vermiculatum							33	33					3.3
Cenchrus ciliaris		83			40	33			25	10		83	26.7
Centaurea alexandrina							33	33					3.3
Centaurea clcitrapa						33			13				3.3
Chenopodium album	33		63	100	40				25	70	33		33.3
Chenopodium murale	67	50	75	100	80	100	33	33	100	70	67	50	70.0
Chenopodium opulifolium	33		25		20					30	33		13.3
Cichorium endivia subsp. divarcatum		17										17	3.3
Convolvulus althaeoides		17										17	3.3
Convolvulus arvensis	33		13							10	33		6.7
Convolvulus lanatus							67	67					6.7
Conyza bonariensis	100	100	100	100	100	100			100	100	100	100	90.0
Cornulaca monacantha							100	100					10.0
Cuscuta pedicillata	33										33		3.3
Cynanchum acutum	67	33	75	100	80	67	100	100	88	70	67	33	70.0
Cynodon dactylon	100	83	75	50	100	33	33	33	50	90	100	83	73.3
Cyperus articulatus	67	17									67	17	10.0
Cyperus rotundus	33	50									33	50	13.3
Dactyloctenium aegyptium					20				13				3.3
Deverra tortuosa							100	100					10.0
Digitaria sanguinalis	33	67	25		40		33	33	13	30	33	67	33.3
Dodonia viscosa	33										33		3.3
Dysphania ambrosioides			13		20					20			6.7
Echinochloa colona				50	20				13	10			6.7
Echinochloa crus-galli		17	13			33			25			17	10.0
Emex spinosa	100	83									100	83	26.7
Eremogone picta							67	67					6.7
Eucalyptus camaldulensis	33										33		3.3
Euphorbia peplis			50		20					50			16.7
Euphorbia peplus			25							20			6.7
Ficus benjamina	33										33		3.3
Foeniculum vulgare		17										17	3.3
Haloxylon scoparium							67	67					6.7
Herniaria hirsuta			13							10			3.3
Hyoscyamus muticus							33	33					3.3

Imperata cylindrica	33	17	13		40					30	33	17	16.7
Launaea nudicaulis					40		67	67	13	10			13.3
Launaea resedifolia			13		20		33	33		20			10.0
Lolium temulentum	67	50									67	50	16.7
Malva aegyptia			13							10			3.3
Malva parviflora	100	83	50	100	60	33			50	60	100	83	60.0
Malva sylvestris	33	50	63	50	20	100			63	50	33	50	46.7
Medicago sativa		17										17	3.3
Melilotus albus	67										67		6.7
Melilotus indicus	100	17	25		60	67			38	40	100	17	36.7
Mesymbrianthemum forsskalii							67	67					6.7
Mesymbrianthemum nodiflorum							33	33					3.3
Moltkiopsis ciliata			13							10			3.3
Neurada procumbens							33	33					3.3
Nicotiana glauca							33	33					3.3
Oloptum miliaceum													3.3
Oxalis pes-carpae	67	17									67	17	10.0
Paspalum distichum	67										67		6.7
Persicaria decipiens		17										17	3.3
Phalaris paradoxa	33	17	25		60	33			25	40	33	17	26.7
Phoenix dactylifera			13							10			3.3
Phragmites australis	67										67		6.7
Pluchea dioscoridis	67	17			20					10	67	17	13.3
Poa annua	33	67	13							10	33	67	20.0
Poa infirma	33		13							10	33		6.7
Polycarpa repens	33		13							10	33		6.7
Polypogon monsepliensis	67	50	75		80				25	80	67	50	50.0
Polypogon viridis			13						13				3.3
Portulaca oleracea	33	17	25	100		100			63	20	33	17	30.0
Pulicaria undulata							67	67					6.7
Raphanus raphanistrum		17										17	3.3
Reichardia tingitana	67	67	13		40		33	33	13	20	67	67	33.3
Rumex dentatus	100	100			20	33			13	10	100	100	36.7
Savignea paviflora							67	67					6.7
Schismus barbatus			50	100	40	33	100	100	50	50			40.0
Senecio glaucus subsp. coronopifolius	67	17	100	100	100	67	67	67	88	100	67	17	73.3
Setaria viridis	33		50	100		67			63	30	33		30.0
Sinapis alba	33	17	13							10	33	17	10.0
Sisymbrium erysimoides	67	67	25							20	67	67	26.7
Sisymbrium irio	100	83	100		20	33			25	80	100	83	60.0
Solanum nigrum	100	67	100	100	100				63	100	100	67	73.3
Sonchus asper	67		63	100	60	33			63	60	67		43.3
Sonchus oleraceus		67	100	100	80	100			88	100		67	70.0
Spergularia diandra							33	33					3.3
Stipellula capensis							33	33					3.3
Symphyotrichum squamatum	33	17	38			33			25	20	33	17	20.0
Tamarix aphylla						33			13				3.3
Tamarix nilotica	33				20		67	67	13		33		13.3
Tribulus terrestris	67	50	25							20	67	50	23.3
Trifolium resupinatum		67										67	13.3
Urospermum picroides		33			20					10		33	10.0
Urtica urens					20					10			3.3
Veronica anagallis-aquatica	33				20					10	33		6.7
Zilla spinosa							100	100					10.0
Total species	58	49	50	20	38	24	36	36	37	57	58	49	111

of species, such as Shannon's (F = 3.28, $p \leq 0.05$). Richness (mean number of species per stand) and equally common species (N1) are also significantly affected by habitat types (F = 4.86 and 3.99, respectively, $p \leq 0.01$). The applied indices indicate that the canal banks habitat is substantially more diverse than any of the other habitats in the present study, followed by the habitat of Limon-Orange crops

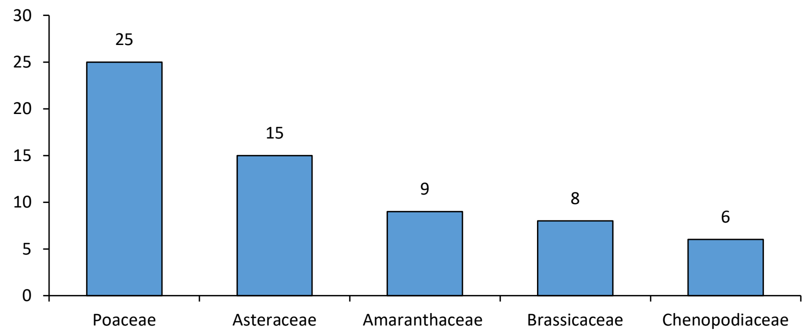


Figure 3. The most represented families in the study area

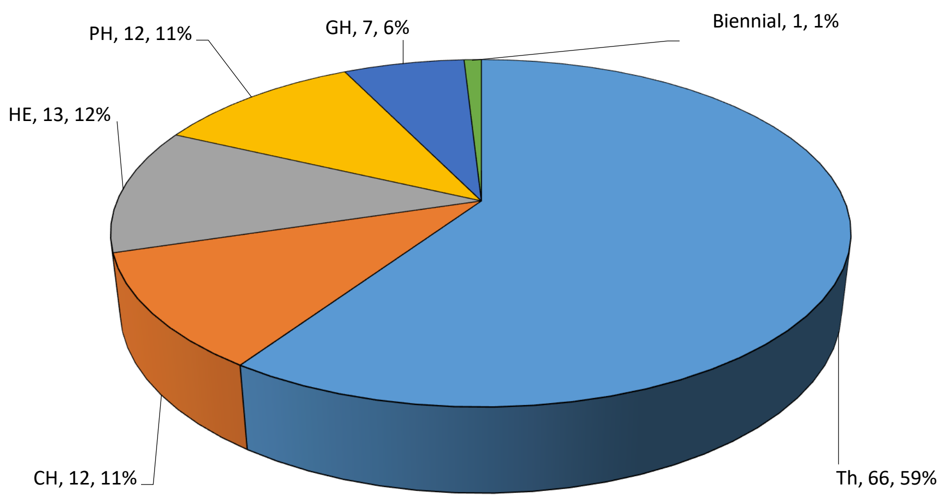


Figure 4. Life form spectrum of the recorded species

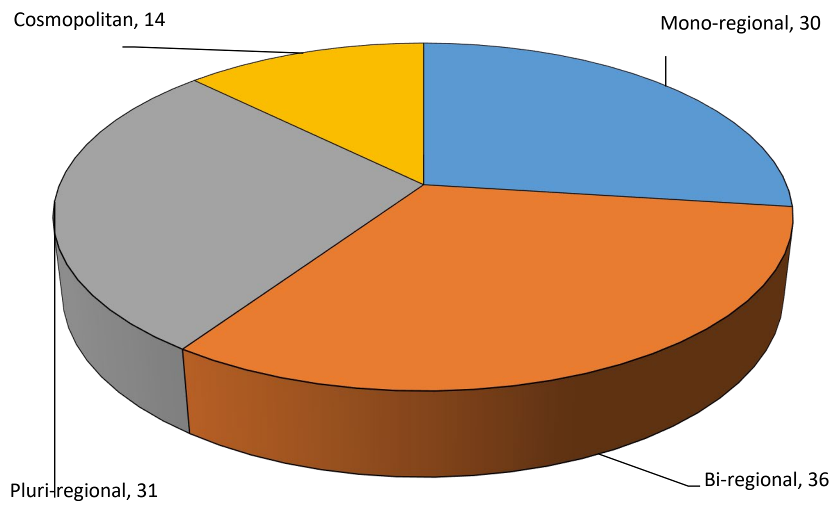


Figure 5. Global geographic distribution of the recorded taxa.

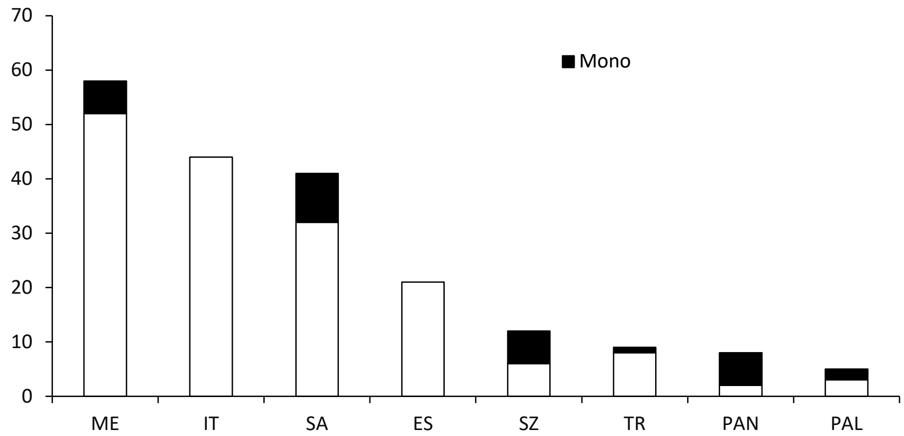
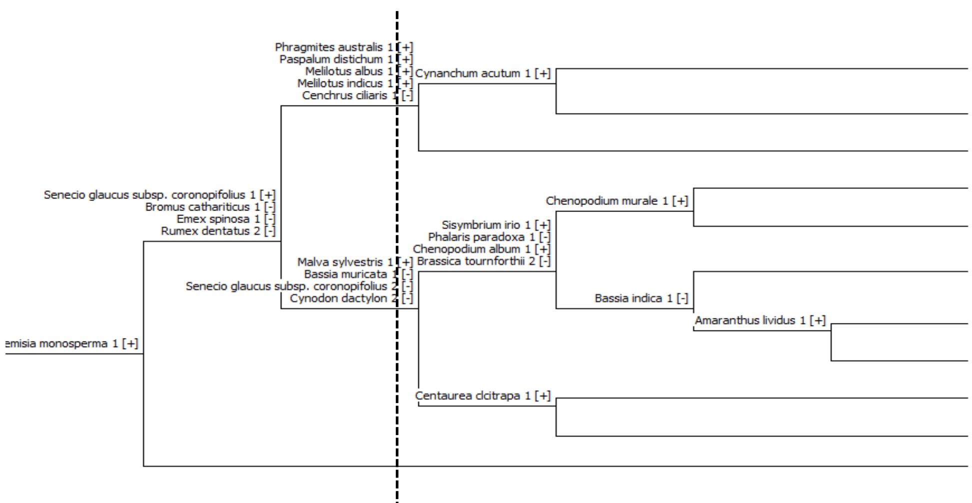


Figure 6. No. of mono-regional species regarding the global distribution.



Figurer 7 TWINSPAN analysis, in the form of a dendrogram, represents the classification of the five vegetation groups. Ⅰ: *Artemisia monosperma*, ⅠⅠ: *Chenopodium murale*, Ⅲ: *Conyza bonariensis*, Ⅳ: *Cynodon dactylon*, and Ⅴ: *Rumex dentatus*.

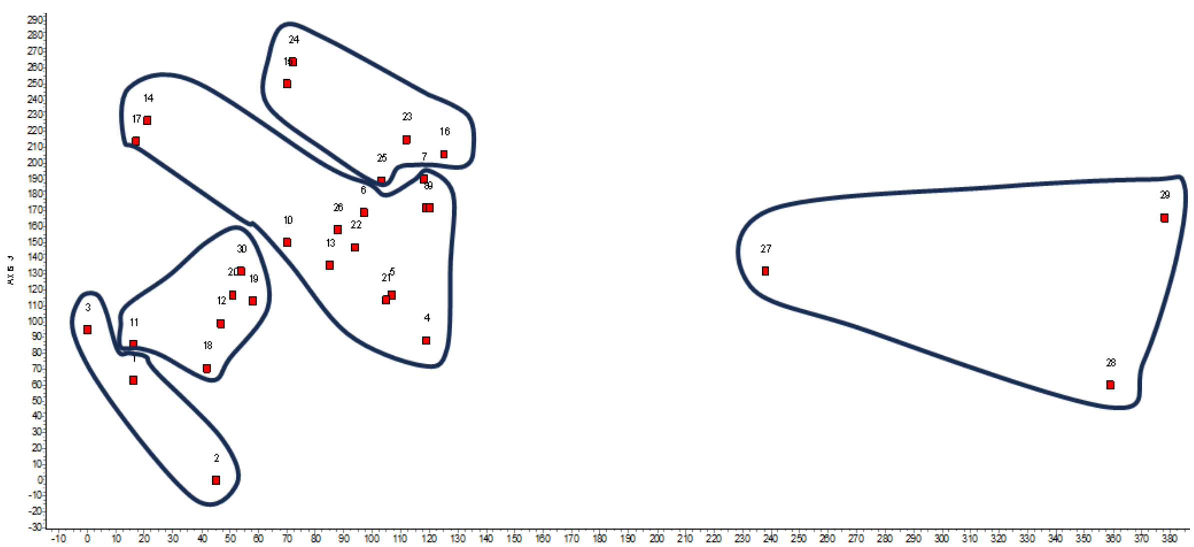


Figure 8. Ordination of the recorded taxa in the study area. Ⅰ: *Artemisia monosperma*, ⅠⅠ: *Chenopodium murale*, Ⅲ: *Conyza bonariensis*, Ⅳ: *Cynodon dactylon*, and Ⅴ: *Rumex dentatus*.

Table 4. Diversity indices and richness across habitats and vegetation groups

		Richness	Simpson	Shannon	N1	E1- Shannon	E5
Habitats	CB	32.00±7.81	0.03±0.01	3.28±0.26	27.24±7.34	0.95±0.01	1.40±0.07
	MD	18.00±6.99	0.04±0.01	2.75±0.30	16.29±5.95	0.97±0.01	1.88±0.46
	LO	19.63±4.69	0.03±0.01	2.86±0.24	17.87±4.22	0.97±0.01	1.96±0.80
	AP	16.50±2.12	0.04±0.01	2.72±0.13	15.20±2.04	0.97±0.00	1.84±0.11
	MG	18.60±6.62	0.04±0.01	2.77±0.33	16.55±5.24	0.96±0.01	1.63±0.22
	PR	17.00±3.00	0.04±0.00	2.72±0.17	15.37±2.58	0.96±0.01	1.82±0.44
	NT	19.33±7.37	0.04±0.03	2.79±0.42	17.10±6.32	0.96±0.01	1.62±0.26
Vegetation groups	I	19.33±7.37	0.04±0.03	2.79±0.42	17.10±6.32	0.96±0.01	1.62±0.26
	II	16.00±2.67	0.04±0.01	2.67±0.17	14.67±2.37	0.97±0.01	2.04±0.68
	III	20.60±5.08	0.04±0.01	2.89±0.25	18.48±4.33	0.96±0.01	1.67±0.42
	IV	32.00±7.81	0.03±0.01	3.28±0.26	27.24±7.34	0.95±0.01	1.40±0.07
	V	18.00±6.99	0.04±0.01	2.75±0.30	16.29±5.95	0.97±0.01	1.88±0.46
Total mean		19.87±6.81	0.04±0.01	2.83±0.30	17.76±5.69	0.96±0.01	1.77±0.50
F-value		4.86**	0.90	3.28*	3.99**	1.04	1.26

Table 5 Soil analysis of the recorded taxa. EC: electric conductivity, SP: saturation percentage and SAR: sodium absorption ratio.

Variable	Vegetation groups					Total mean	F-value
	I	II	III	IV	V		
pH	8.33±0.03	7.44±0.15	8.17±0.07	7.94±0.60	8.18±0.05	7.96±0.41	4.60*
EC	2.64±1.43	7.75±2.49	4.10±0.03	5.94±4.22	4.56±0.35	5.25±2.63	1.71
Ca^{++}	7.10±2.12	26.33±6.38	16.00±0.00	18.60±13.29	17.10±1.27	17.87±8.49	2.59
OM	0.24±0.04	0.55±0.32	0.39±0.05	0.77±0.76	0.76±0.69	0.54±0.41	0.52
$CaCO_3$	2.18±0.18	2.45±1.13	2.42±0.44	3.40±1.13	2.80±0.85	2.63±0.81	0.58
Gravel	1.22±0.02	3.73±3.40	3.15±0.49	3.00±2.55	3.42±3.08	2.98±2.19	0.32
Sand	98.00±0.00	95.00±1.73	95.50±2.12	86.00±11.31	88.50±12.02	92.82±7.04	1.28
Silt	1.25±0.35	3.33±1.44	2.50±1.41	7.00±4.24	5.00±4.24	3.77±2.88	1.43
Clay	0.75±0.35	1.67±0.29	2.00±0.71	7.00±7.07	6.50±7.78	3.41±4.28	0.97
SP	18.50±0.71	19.67±1.53	20.50±2.12	29.00±12.73	27.50±12.02	22.73±7.17	0.94
Mg^{++}	3.70±2.12	21.83±4.25	12.50±0.71	12.90±10.04	12.65±1.91	13.55±7.42	4.17
Na^{+}	6.80±3.82	26.53±7.42	15.20±0.85	17.30±14.42	13.50±2.12	16.84±9.22	2.27
K^{+}	0.67±0.49	2.03±0.45	1.56±0.08	1.32±1.11	1.46±0.23	1.46±0.65	1.77
HCO_3^{-}	4.30±2.69	21.47±7.80	14.80±0.28	13.15±9.69	13.65±0.92	14.20±7.63	2.40
Cl^{-}	6.45±2.62	25.63±6.60	13.60±0.99	16.00±12.73	12.55±1.48	15.83±8.69	2.87
SO_4^{--}	7.52±3.25	29.63±5.00	16.86±2.91	20.97±16.45	18.51±4.96	19.69±9.90	2.53
SAR	2.85±1.09	5.36±0.91	4.03±0.18	4.10±2.14	3.50±0.36	4.09±1.27	1.72
TDS	1689.6±914.2	6202.7±1995.2	2624.0±18.1	4512.0±3710.9	2918.4±226.3	3826.9±2327.5	2.09
N	1.56±0.08	1.74±0.74	1.50±0.00	2.21±1.68	2.62±1.10	1.91±0.84	0.54
P	13.00±1.41	13.67±5.69	10.25±1.06	17.50±7.78	18.75±8.84	14.55±5.51	0.70
K	124.00±2.83	116.33±3.06	114.50±3.54	121.00±8.49	127.00±2.83	120.18±5.93	2.93
Fe	1.02±0.11	0.67±0.15	0.76±0.13	0.97±0.76	1.08±0.32	0.88±0.32	0.59
Zn	0.24±0.03	0.28±0.05	0.25±0.04	0.48±0.23	0.63±0.40	0.36±0.22	1.67
Mn	0.24±0.06	0.18±0.06	0.17±0.05	0.53±0.49	0.54±0.31	0.32±0.25	1.30
Cu	0.05±0.03	0.05±0.02	0.06±0.02	0.07±0.06	0.07±0.03	0.06±0.03	0.19

H' = 3.28±0.26and 2.86±0.24, respectively, with the highest mean of species richness per stand 32.00±7.81 and 19.63±4.69, respectively, where the dominance is consequently lower D = 0.03±0.01 each (Table 4). Regarding the vegetation groups in the study area, the highest number species 32.00±7.81 was recorded in vegetation group IV, dominated by *Cynodon dactylon*, while the lowest number of species 16.00±2.67was recorded in vegetation group II, dominated by *Chenopodium murale.* This coincides with the highest species diversity (H' = 3.28±0.26) in *Cynodon dactylon* group, and the lowest species diversity 2.67±0.17 in *Chenopodium murale* group.

Edaphic factors and vegetation communities

Soil analysis revealed that vegetation groups II, IV, and V exhibit the highest values for most soil parameters, while groups I and III have the lowest values (Table 5). Group II recorded the highest values for electrical conductivity (EC) (7.75), calcium (Ca^{2+}) (26.33 meq/l), magnesium (Mg^{2+}) (21.83 meq/l), sodium (Na^{+}) (26.53 meq/l), potassium (K^{+}) (2.03 meq/l), bicarbonate (HCO3-) (21.47 meq/l), chloride (Cl^{-}) (25.63 meq/l), sulfate ($SO4^{2-}$) (29.63 meq/l), sodium absorption ratio (SAR) (5.36), and total dissolved salts (TDS) (6202.67 ppm). Group IV had the highest levels of copper (Cu)

(0.07 ppm), organic matter (OM) (0.77%), calcium carbonate ($CaCO_3$) (3.40%), silt (7%), clay (75%), and saturation percentage (29%). Group V showed the highest values for nitrogen (N) (2.62 ppm), phosphorus (P) (18.75 ppm), potassium (K) (127 ppm), iron (Fe) (1.08 ppm), zinc (Zn) (0.63 ppm), manganese (Mn) (0.54 ppm), and copper (Cu) (0.07 ppm). In contrast, Group I exhibited the highest pH (8.33) and sand content (98%). Meanwhile, Group II had the lowest values for pH (7.44), Fe (0.67 ppm), and Cu (0.05 ppm). Group III recorded the lowest values for N (1.5 ppm), P (10.25 ppm), K (114.5 ppm), and Mn (0.17 ppm). Group I, representing natural stands, had the lowest levels for the remaining soil parameters. Overall, most parameter concentrations showed no significant differences across the studied groups, except for pH, which displayed significant variation.

DISCUSSION

Floristic composition

The recorded 111 taxa, representing 86 genera and 29 families, highlights the rich biodiversity of the study area. The predominance of annual species (59.5%) reflects the ephemeral nature of vegetation in response to seasonal and climatic variability, consistent with observations in other semi-arid and Mediterranean ecosystems. The presence of 18 alien species, including invasive taxa like *Bassia indica* and *Persicaria decipiens*, underscores the growing influence of human activities on plant invasions. Alien species, particularly invasive ones, can significantly alter ecosystem dynamics, emphasizing the need for targeted management and control strategies (Sheded, 2002; Hulme, 2006; Seastedt, 2015). The dominance of therophytes (66.59%) in the life form spectrum aligns with the arid conditions and seasonal rainfall of the region, favoring species with short life cycles.

The biogeographical affinities of the flora, with a strong representation of Mediterranean elements (52 species), reflect the geographical location and climatic conditions, bridging the Mediterranean and Saharo-Arabian regions. The significant contribution of bi-regional and pluri-regional elements suggests a diverse ecological history and adaptation to varying environmental conditions. The recorded species (111) represent approximately 5.2% of the Egyptian flora, 11.4% of its genera, and 22.5% of its families (Boulos, 2009). The study area lies within the Western Desert phytogeographic region of Egypt, where climatic changes have resulted in poor vegetation diversity and cover. Prolonged droughts, often exceeding a decade, have caused significant vegetation loss and the probable extinction of some species (Boulos, 2009).

The five dominant families based on species count were Poaceae (25 species), Asteraceae (15 species), Amaranthaceae (9 species), Brassicaceae (8 species), and Chenopodiaceae (6 species), collectively accounting for 56.8% of the total taxa. These families are characteristic of the Mediterranean North African flora (Quézel, 1978) and are similarly significant in small-scale farming systems in highland Peru, central Mexico, and northern Zambia (Vibrans, 1998). This trend mirrors findings from studies on the weed flora of desert-reclaimed arable lands in southern Egypt (Salama et al., 2016), the urban flora of Alexandria (Heneidy et al., 2021), and the overall Egyptian flora (Boulos, 2009).

Approximately 43.6% of the recorded species were perennials, while 59.5% were annual. The dominance of annuals is attributed to the warm-dry climate, topographic effects, and biotic disturbances (Heneidy & Bidak, 2001), along with their high reproductive capacity and ecological, morphological, and genetic plasticity under disturbed conditions (Grime, 1979). Their short life cycles, combined with harsh climatic conditions and scarcity moisture, allow annual species to thrive during favorable seasons. Conversely, the low number of perennials (44 species, 43.6%) may be due to intensive land management practices such as ploughing, sub-soiling, and harrowing, which affect their vegetative growth and life cycles (Salama et al., 2016). A decline in desert perennials in reclaimed lands suggests a replacement of xerophytic species with mesophytic and canal bank species, as also reported by Abd El-Ghani et al. (2013).

Sixty-two species were identified as weeds associated with cultivated plants. The wide distribution of certain species, such as *Conyza bonariensis*, *Sonchus oleraceus*, *Cynodon dactylon*, *Senecio glaucus* subsp. *coronopifolius*, and *Chenopodium murale*, is likely due to their phenotypic plasticity and ecological versatility (Shaltout & Sharaf El-Din, 1988). In contrast, the restricted distribution of other weeds may result from habitat preference, crop type, seasonal conditions, and ecological factors (Salama et al., 2016). Desert species were more prevalent in limon-Orange (50 species) and alfalfa fields (49 species), likely due to the reduced ploughing in these crops. Some weed species are native to Egypt, while others are segetal and ruderal species introduced through agricultural practices and land-use changes. These anthropogenic environments, with altered thermal and moisture regimes, provide niches for the recruitment of specific species with dispersal, physiological, and morphological traits (Lausi and Nimis, 1985).

Out of the 136 alien species documented in Egypt (Shaltout et al., 2016), 18 (13.2%) were recorded in this study, including six causal, ten naturalized, and two invasive species (*Bassia indica* and *Persicaria decipiens*). *Bassia indica*, introduced from India in 1930 as fodder, has become an aggressive invader (Draz, 1954). *Ipomoea carnea*, introduced from South America for ornamental use in 1932 (Austin, 1977), is now naturalized along Nile Delta watercourses (Shaltout et al., 2010). Agricultural developments, such as embankments and ditches, have facilitated the spread of new alien species (Jehlík et al., 2017).

Phytogeographically, Egypt lies at the intersection of four floristic regions: Sudano-Zambezian, Irano-Turanian, Saharo-Arabian, and Mediterranean (El Hadidi, 1993). The recorded flora shows a dominance of bi- and pluri-regional elements, with fewer mono-regional and Cosmopolitan species, reflecting human disturbances in the study area (Shaltout & El-Fahar, 1991; Abd El-Ghani et al., 2012). The Saharo-Arabian species, either pure or penetrated other regions, dominate the flora and serve as indicators of hot arid climates. Similar patterns have been observed in reclaimed areas across Egypt (e.g., El-Amry, 1981; Soliman, 1989; Mustafa, 2002; Shaheen, 2002; Abd El-Ghani & Fawzy, 2006; Salama et al., 2016).

Plant communities and habitat associations

The identification of five distinct vegetation groups through TWINSPAN and their segregation in ordination analysis indicates clear ecological stratification driven by habitat types. The *Cynodon dactylon* community, associated with canal banks, exhibited the highest species richness and diversity. This can be attributed to the microhabitats and moisture availability created by canal systems, which act as ecological corridors. The dominance of weeds in this habitat (72.41%) further reflects the anthropogenic influence on these environments. In contrast, the *Chenopodium murale* community, representing various habitats, exhibited the lowest species richness and diversity. This group's prevalence in degraded or disturbed areas highlights its role as a colonizer and its adaptability to stressful conditions, as reported in previous studies. Similarly, the *Artemisia monosperma* community, restricted to natural habitats, reflects a more stable and less disturbed ecosystem. In terms of classification, the associated vegetation can be divided into five vegetation groups; groups that is dominated by *Artemisia monosperma*, representing the natural habitat. Group II which is dominated by *Chenopodium murale*, represents a variety of habitats. Group III: Dominated by *Conyza bonariensis*, representing the limon-Orange habitat. Group IV, dominated by *Cynodon dactylon*, represents canal bank habitats; and group V that is dominated by *Rumex dentatus*, representing alfa-alfa fields. Most of these communities were identified by Salama et al. (2016) in desert-reclaimed arable lands of southern Egypt, while some were also recorded in similar studies (Abd El-Ghani, 1994; Abd El-Ghani et al., 2012 and 2015). This classification highlights the significant effects of both crop type and season on weed community composition and structure. The vegetation groups identified through classification in the present study were also separated along the first two DECORANA ordination axes, reinforcing the importance of crop type and season in shaping weed communities. These findings align with those of Andersson and Milberg (1998), who emphasized the role of season and crop type in determining weed community composition. Fertilization regimes, soil management practices, herbicide applications, and weed management strategies, which vary depending on crop type, may also exert significant influence (Légere & Samson, 1999; Leeson et al., 2000).

Diversity pattern, edaphic factors and habitat influence

Soil analysis revealed distinct edaphic profiles among the vegetation groups, with significant implications for vegetation patterns. High organic matter, nutrient content, and clay percentage in the *Cynodon dactylon* and *Rumex dentatus* communities support higher species richness and diversity. These findings are consistent with studies emphasizing the role of environmental variables particularly soil fertility and texture in supporting diverse plant communities and shaping the distribution pattern in the agroecosystems (e.g., Al-Qahtani, 2019). The soil near tracks often contains elevated levels of pollutants, such as oil residues and heavy metals and is frequently dry and stony (Wiłkomirski et al., 2011). Plant species that thrive in these habitats must tolerate these unfavorable conditions. Additionally, plants growing along tracks are often subjected to herbicide application, trampling, and mechanical disturbances from vehicle traffic (Sudnik-Wójcikowska & Galera, 2005; Liu et al., 2009). Consequently, weeds and invasive species often constitute a significant portion of the flora in these areas. Despite this, such habitats can still support rare and valuable species. The presence of two endemic species, *Sinapis allionii* and *Sonchus macrocarpus*, in the studied urban habitats confirms that railway and tram corridors can serve as critical refuges for rare and endangered species. Moreover, vegetation in these habitats can provide various ecological and functional benefits (Májeková et al., 2016).

The degree of biodiversity in agroecosystems is influenced by vegetation diversity, crop permanence, management intensity, and isolation from natural vegetation (Southwood and Way, 1970). Canal banks supported the highest number of species (58, 72.41% weeds), followed by limon-Orange farms (50, 74% weeds) and Medicago fields (49, 71.43%). In contrast, Apricot farms, which require high pesticide use, supported the lowest number of species (20).

The *Chenopodium murale* community, associated with the lowest pH and nutrient levels, reflects its tolerance to saline and nutrient-poor conditions, indicative of a stress-adapted strategy. Conversely, the natural habitats in the *Artemisia monosperma* community exhibited lower soil nutrient values, highlighting the fragile nature of these ecosystems and their reliance on specific adaptations to survive. The adaptation of these species in response to environmental stress including salinity, drought, and low nutrients content documented in the structural and chemical features of these plants (El-Sherbeny et al., 2021).

Variations in species diversity indices indicated high overall diversity across all vegetation groups and habitats, with slight differences among them. Shannon's diversity index (*H'*) ranged from 2.28 to 3.28, accompanied by low dominance, as confirmed by Simpson's index (*D*, ranging from 0.03 to 0.04). Hill's number (*N1*) indicated about two to three equally common species in the vegetation groups, suggesting increased evenness in species abundance (evenness index *E1* ranged from 0.95 to 0.97). The *Chenopodium murale* community (Group II) was the least diverse, as evidenced by its Shannon index (*H'* = 2.67) and highest dominance (*D* = 0.04), with three equally common species sharing dominance. In contrast, the highest species count (58) was recorded in Group IV (*Cynodon dactylon*), while the lowest counts were observed in Groups I (*Artemisia monosperma*, 36 species) and II (*Chenopodium murale*, 37 species).

The significant variation in diversity indices among habitat types underscores the influence of environmental factors on species distribution and wealth. The canal banks and Limon-Orange farms supported higher diversity, richness, and evenness due to their heterogeneity and resource availability. Shannon's index values, indicating the balance between species richness and evenness, reaffirm the ecological importance of canal banks as a diversity hotspot in these agroecosystems. Conversely, the Apricot farms, with the lowest species richness and a dominance of weeds, reflect limited habitat complexity and potential overuse of agrochemicals. Agroecosystems are characterized by the presence of agrochemicals such as pesticides, fertilizers, and plant growth regulators. The magnitude and extent of the agrochemical contamination will vary, depending upon the crops cultivated (Hodgson, 2012; Alengebawy et al., 2021; Dhuldhaj et al., 2023). The wild plant species diversity in agroecosystems is influenced by agrochemical utilization (Qi, et al., 2016; Teixeira et al., 2021).

CONCLUSION

The results of this study provide a comprehensive analysis of the floristic composition, plant communities, diversity pattern, and edaphic factors influencing vegetation in agroecosystem of reclaimed deserts in the western desert of Egypt. Using TWINSPAN and ordination techniques, the study identified five distinct vegetation groups, each associated with unique habitat characteristics and dominant species. Diversity indices revealed significant variations in species richness and evenness among habitats, with canal banks exhibiting the highest diversity. Furthermore, edaphic factors such as organic matter content, soil texture, and nutrient availability played a key role in shaping vegetation patterns and community structure. These findings provide critical insights into the interplay between vegetation and environmental gradients, offering a baseline for informed ecological management and conservation strategies. The findings highlight the significant role of habitat heterogeneity and soil properties in shaping vegetation patterns. The prevalence of alien species and weeds in disturbed habitats calls for integrated management approaches to control invasive species and restore ecosystem balance. Conservation strategies should prioritize canal banks and other biodiversity-rich habitats to sustain their ecological functions. Additionally, the low diversity in agricultural lands suggests a need for sustainable farming practices that promote agro-biodiversity. Measures such as crop rotation, reduced chemical inputs, and habitat corridors can mitigate biodiversity loss in these areas. Exploration of temporal changes in vegetation patterns, the functional traits of species, and their ecological roles is recommended for future studies.

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AVAILABILITY OF DATA AND MATERIALS

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

COMPETING INTERESTS

The authors declare no competing interests.

REFERENCES

Abd El-Ghani, M.A. (1994) Weed plant communities of orchards in Siwa Oasis, Egypt. *Feddes Repertorium*, 105 (3-4), 243-250.

Abd El-Ghani, M.M., Fawzy, A.M. (2006) Plant diversity around springs and wells in five oases of the Western Desert, Egypt. *International Journal of Agriculture and Biology*, 8(2), 249-255.

Abd El-Ghani, M.A., Shehata, M.N., Mobarak, A., Bakr, R. (2012) Factors affecting the diversity and distribution of synanthropic vegetation in urban habitats of the Nile Delta, Egypt. *Rendiconti Lincei*, 23, 327-337.

Abd El-Ghani, M.M., Salama, F.M., Salem, B., El-Hadidy, A., Abdel-Aleem, M. (2013) Biogeographical relations of a hyperarid desert flora in eastern Egypt. *African Journal of Ecology*, 52, 173 –191.

Abd El-Ghani, M. M., Abou-El-Enain, M. M., Aboel-Atta, A. I., Hussein, E. A. (2015) Composition, distribution patterns and habitat divergence of street trees in the greater Cairo city, Egypt. *Assiut University Bulletin for Environmental Researches*, 18(1), 59-91.

Alary, V., Aboul-Naga, A., Osman, M.A., Daoud, I., Abdelraheem, S., Salah, E., Juanes, X., Bonnet, P. (2018) Desert land reclamation programs and family land dynamics in the Western Desert of the Nile Delta (Egypt), 1960–2010. *World Development*, 104,140-153. https://doi.org/10.1016/j.worlddev.2017.11.017.

Alengebawy, A., Abdelkhalek, S. T., Qureshi, S. R., Wang, M. Q. (2021). Heavy metals and pesticides toxicity in agricultural soil and plants: Ecological risks and human health implications. *Toxics*, 9(3), 42.

Allen, S.E., Grimshaw, H.M., Parkinson, J.A., Quarmby, C., Roberts, J.D. (1986) *Chemical analysis. In Methods in Plant Ecology*; Moore, P.D., Chapman, S.B., Eds.; Blackwell Scientific Publications: Oxford, UK, pp. 285–344.

Al-Qahtani, S. M. (2019) Effect of soil properties on the diversity and distribution of weeds in citrus farms in arid region. *Applied Ecology & Environmental Research*, 17(1).

Altieri, M.A., Nicholls, C.I. (2018). Urban Agroecology: designing biodiverse, productive and resilient city farms. *Agro Sur*, 46(2), 49-60. DOI:10.4206/agrosur.2018.v46n2-07

Anderson, J. E., Inouye, R. S. (2001) Landscape-scale changes in plant species abundance and biodiversity of a sagebrush steppe over 45 years. *Ecological monographs*, 71(4), 531-556.

Andersson, T. N., Milberg, P. (1998) Weed flora and the relative importance of site, crop, crop rotation, and nitrogen. *Weed Science*, 46(1), 30-38.

Austin, D.F. (1977). *Ipomoea carnea* Jacq. vs. *Ipomoea fis*tulosa Mart. ex Choisy. *Taxon*, 26, 235-238.

Austin, D. F. (1997) Dissolution of *Ipomoea* ser. Anisomerae (Convolvulaceae). *Journal of the Torrey Botanical Society*, 142,140-159.

Bakr, N., Bahnassy, M.H. (2019) Egyptian Natural Resources. In *The Soils of Egypt*; El-Ramady, H., Alshaal, T., Bakr, N., Elbana, T., Mohamed, E., Belal, A.A., Eds.; World Soils Book Series; Springer: Cham, Switzerland; pp. 33–49.

Balkhair, K.S., Ashraf, M.A. (2016) Field Accumulation Risks of Heavy Metals in Soil and Vegetable Crop Irrigated with Sewage Water in Western Region of Saudi Arabia. *Saudi Journal of Biological Sciences*, 23, S32-S44. https://doi.org/10.1016/j.sjbs.2015.09.023

Beek, K.J. (1978) *Land evaluation for agricultural development*. ILRI Publication 23. ILRI, Wageningen.

Boulos, L. (1999-2005) *Flora of Egypt*: Volumes 1-4. Al–Hadara Publishing, Cairo.

Boulos, L. (2009) **"***Flora of Egypt*'*s Checklist***"**, Revised Annotated Edition. Cairo, Al- Hadara publishing (pp 410).

Dhuldhaj, U. P., Singh, R., Singh, V. K. (2023) Pesticide contamination in agro-ecosystems: toxicity, impacts, and bio-based management strategies. *Environmental Science and Pollution Research*, 30(4), 9243-9270.

Draz, O. (1954) Range management a world problem. *Journal of Range Management*, 7(3), 112-114.

El Hadidi, M. N. (1993) *Natural vegetation*. – In: Craig G. M. [ed.]: The agriculture in Egypt. –London: Oxford University Press.

El-Amry, M.I. (1981) *Plant life in Minia Province, Egypt*. M. Sc. Thesis, Fac. of Sci. Cairo Univ., pp: 311.

El-Fahar, R. A., Sheded, M. G. (2002) Weed flora in plantation of recent established tourist resorts in the Western Mediterranean coast of Egypt. *Egyptian Journal of Biotechnology*, 11, 330-343.

El-Guindy, S. (2006*) The use of brackish water in agriculture and aquaculture*. Panel Project on Water Management

Work-shop on brackish water use in agriculture and aquaculture.2–5 December 2006, Cairo, Egypt.

Elsharkawy, M. M., Omara, R. I., Mostafa, Y. S., Alamri, S. A., Hashem, M., Alrumman, S. A., Ahmad, A. A. (2022). Mechanism of Wheat Leaf Rust Control Using Chitosan Nanoparticles and Salicylic Acid. *Journal of Fungi*, 8(3), 304. https://doi.org/10.3390/jof8030304

El-Sherbeny, G. A., Dakhil, M. A., Eid, E. M., Abdelaal, M. (2021) Structural and chemical adaptations of *Artemisia monosperma* Delile and *Limbarda crithmoides* (L.) Dumort. in response to arid coastal environments along the Mediterranean Coast of Egypt. *Plants*, 10(3), 481.

FAO (1985) *Guidelines: land evaluation for irrigated agriculture*. Soils Bulletin 55. Food and Agriculture Organization of the United Nations, Rome, Italy.

Feinbrun-Dothan, N. (1977) *Flora Palaestina*, Part 3: Ericaceae to Compositae; Israel Academy of Sciences and Humanities: Jerusalem, Palestine.

Feinbrun-Dothan, N. (1978) *Flora Palaestina* Part 4: Alismataceae to Orchidaceae; Israel Academy of Sciences and Humanities: Jerusalem, Palestine.

Gall, J. E., Boyd, R. S., Rajakaruna, N. (2015) Transfer of heavy metals through terrestrial food webs: a review. *Environmental monitoring and assessment*, 187, 1-21.

Garbach, K., Milder, J. C., Montenegro, M., Karp, D. S., DeClerck, F. A. (2014) Biodiversity and Ecosystem Services in Agroecosystems. *Encyclopedia of Agriculture and Food Systems,* 2, 21-40. 10.1016/B978-0-444-52512-3.00013-9.

Gauch, H.G., Whittaker, R.H. (1981) Hierarchical classification of community data. *Journal of Ecology*, 69, 537–558.

Grime, J. P. (1979). *Plant strategies and vegetation processes*. – Chichester: John Wiley & Sons.

Heneidy, S.Z., Bidak, L.M. (2001). Multipurpose plant species in Bisha, Asir region, southwestern Saudi Arabia. *Journal of King Saud University*, 13 (Science: 1 and 2), 11–26.

Heneidy, S.Z., Halmy, M.W., Toto, S.M., Hamouda, S.K., Fakhry, A.M., Bidak, L.M., Eid, E.M., Al-Sodany, Y.M. (2021) Pattern of Urban Flora in Intra-City Railway Habitats (Alexandria, Egypt): A Conservation Perspective. *Biology*, 10, 698.

Hill, M.O. (1979 a) *TWINSPAN A Fortran Program for Arranging Multivariate Data in An Ordered Two-Way Table by Classification the Individuals and The Attributes*; Cornell University: Ithaca, NY, USA.

Hill, M.O. (1979 b) *DECORANA A Fortran Program for Detrended Correspondence Analysis and Reciprocal Averaging*; Cornell University: Ithaca, NY, USA.

Hodgson, W. (2012) "*Pre-Colombian agaves: living plants linking an ancient past in Arizona*", in Explorations in Ethnobiology: The Legacy of Amadeo Rea, edited by Quinlan M, Lepofsky D. Denton, TX: Society for Ethnobiology. pp. 78–103.

Hulme, P. E. (2006) Beyond control: wider implications for the management of biological invasions. *Journal of Applied Ecology*, 43(5), 835-847.

Jehlík, V., ZaliberováJana, M., Májeková, M. (2017) The influence of the Eastern migration route on the Slovak flora - A comparison after 40 years. *Tuexenia*, 37(1), 313-332.

Lausi, D., Nimis, P.L. (1985) *Quantitative phytogeography of the Yukon Territory (NW Canada) on a chorological-phytosociological basis*. In: Neuhäusl, R., Dierschke, H., Barkman, J.J. (eds). Chorological phenomena in plant communities. Advances in vegetation science, vol 5. Springer, Dordrecht. https://doi.org/10.1007/978-94-009-5508-0_3

Leeson, S., Summers, J.D., Caston, L.J., (2000) Net energy to improve pullet growth with low protein amino acid-fortified diets. *Journal of Applied Poultry Research*, 9, 384–392.

Légere, A., Samson, N. (1999) Relative influence of crop rotation, tillage, and weed management on weed associations in spring barley cropping systems. *Weed Science*, 47(1), 112-122. DOI: 10.1017/S0043174500090731

Liu, H., Chen, L.P., Ai, Y.W., Yang, X., Yu, Y.H., Zuo, Y.B., Fu, G.Y. (2009) Heavy metal contamination in soil alongside mountain railway in Sichuan, China. *Environmental Monitoring and Assessment*, 152, 25–33.

Liu, K., Bandara, M., Hamel, C., Knight, J.D., Gan, Y. (2020). Intensifying crop rotations with pulse crops enhances system productivity and soil organic carbon in semi-arid environments. *Field Crops Research*, 248, 107657. https://doi.org/10.1016/J.FCR.2019.107657.

Magurran, A.E. (2004) Measuring Biological Diversity; Blackwell Publishing: Oxford, UK, pp. 256.

Májeková, M., Paal, T., Plowman, N.S., Bryndova, A., Kasari, L., Norberg, A. (2016) Evaluating functional diversity: missing trait data and the importance of species abundance structure and data transformation. *PloS one*, 11 (2), e0149270.

Mueller-Dombois, D., Ellenberg, H. (1974) *Aims and Methods of Vegetation Ecology*. John Wiley and Sons, New York, pp. 547.

Mustafa, G.A. (2002) *Some aspects of biodiversity in the weed flora in the farmlands of upper Egypt*. M.Sc. Thesis, Cairo University.

Nagajyoti, P.C., Lee, K.D., Sreekanth, T.V. (2010). Heavy metals, occurrence and toxicity for plants: a review. *Environmental Chemistry Letters*, 8, 199–216 https://doi.org/10.1007/s10311-010-0297-8

Negm, A., Saavedra, O., Eladawy, A. (2016) *Nile Delta Biography: Challenges and Opportunities*. In: "The Nile Delta", A.M. Negm (Ed.), pp. 3-18. Springer Cham.

Okeke, E.S., Okoye, C.O., Atakpa, E.O., Ita, R.E., Nyaruaba, R., Mgbechidinma, C.L., Akan, O.D. (2022) Microplastics in agroecosystems-impacts on ecosystem functions and food chain. *Resources, Conservation and Recycling*, 177, 105961, https://doi.org/10.1016/j.resconrec.2021.105961.

Palmer, M.W. (1993) Putting things in even better order: The advantages of canonical correspondence analysis. *Ecology*, 74, 2215–2230.

Peel, M. C., Finlayson, B. L., McMahon, T. A. (2007) Updated world map of the Köppen-Geiger climate classification. *Hydrology and earth system sciences*, *11*(5), 1633-1644.

Qi, Y., Li, J., Yan, B., Deng, Z., Fu, G. (2016) Impact of herbicides on wild plant diversity in agro-ecosystems: A review. *Biodiversity Science*, 24(2), 228.

Quézel, P. (1978). Analysis of the flora of Mediterranean and Saharan Africa. *Annals of the Missouri Botanical Garden*, 479-534.

Radwan, T.M. (2019) Monitoring Agricultural Expansion in a Newly Reclaimed Area in the Western Nile Delta of Egypt Using Landsat Imageries. *Agriculture*, 9, 137. DOI:10.3390/AGRICULTURE9070137

Randall, N., Smith, B. (2020) Biodiversity In: *The biology of agroecosystems*. Oxford University Press. https://doi.org/10.1093/oso/9780198737520.003.0003

Raunkiaer, C. (1937) *Plant Life Forms*; Clarendon: Oxford, UK, pp. 104.

Rossiter, D.G. (1996) A theoretical framework for land evaluation. *Geoderma*, 72, 165-202.

Sadek, S. (2011) *An overview on desert aquaculture in Egypt*. In V. Crespi & A. Lovatelli, eds. Aquaculture in desert and arid lands: development constraints and opportunities. FAO Technical Workshop. 6–9 July 2010, Hermosillo, Mexico. FAO Fisheries and Aquaculture Proceedings No. 20. Rome, FAO. 2011. pp. 141–158.

Salama, F., Abd El-Ghani, M., Gadallah, M., El-Naggar, S., Amro, A. (2016) Characteristics of desert vegetation along four transects in the arid environment of southern Egypt. *Turkish Journal of Botany*, 40(1), 59 – 73.

Seastedt, T. R. (2015) Biological control of invasive plant species: a reassessment for the A nthropocene. *New phytologist*, 205(2), 490-502.

Shaheen, A.M. (2002) Weed diversity of newly farmed land on the Southern Border of Egypt (Eastern and Western Shores of Lake Nasser). *Pakistan Journal of Biological Science*, 5, 802-806.

Shaltout, K.H., Sharaf El-Din, A. (1988) Habitat types and plant communities along transect in the Nile Delta region. *Feddes Repertorium* 99, 153–162.

Shaltout, K. H., El Fahar, R. A. (1991) Diversity and phenology of weed communities in the Nile Delta region. *Journal of Vegetgation Science*, 2, 385 –390.

Shaltout, K.H., Sharaf El-Din, A., Ahmed, D.A. (2010) *Plant life in the Nile Delta*. Tanta: Tanta University Press. 158p.

Shaltout, K.H., Hosni, H.A., El-Kady, H.F., El-Beheiry, M.A., Shaltout, S.K. (2016) Composition and pattern of alien species in the Egyptian flora. *Flora*, 222, 104-110.

Sheded, M. (2002) *Invasive weed species in Tuskha Area, Southwest of Egypt*. Proc.2nd Int. Confe. Bio. Sci (ICBS), Fac. Sci ., Tanta University, 27-28 April 2002 .Vol 2:1-13.

Soliman, G.F. (1989) The hydrology of lake Qarun, Fayum, Egypt. Part II; The successive increase of salinity. *Bulletin of the National Institute of Oceanography and Fisheries*, 15, 93–105.

Southwood, R.E., Way, M.J. (1970) *Ecological background to pest management*. In: Rabb, R.C., Guthrie, F.E. (Eds.), Concepts of Pest Management. North Carolina State University, Raleigh, NC, pp. 6–29

Stirling, G., Wilsey, B. (2001) Empirical relationships between species richness, evenness, and proportional diversity. *American Naturalist*, 158, 286–299.

Sudnik-Wójcikowska, B., Galera, H. (2005) Floristic differences in some anthropogenic habitats in Warsaw. *Annales Botanici Fennici*, 42, 185–193.

Teixeira, H. M., Bianchi, F. J., Cardoso, I. M., Tittonell, P., Pena-Claros, M. (2021) Impact of agroecological management on plant diversity and soil-based ecosystem services in pasture and coffee systems in the Atlantic Forest of Brazil. *Agriculture, Ecosystems & Environment*, 305, 107171.

TerBraak, C.J., Looman, C.W. (1987) *Regression*. In Data Analysis in Community and Landscape Ecology; Jongman, R.H.G., TerBraak, C.J.F., van Tongeren, O.F.R., Eds.; Pudoc: Wageningen, The Netherlands.

Tutic, A., Novakovic, S., Lutovac, M., Biocanin, R., Ketin, S., Omerovic, N. (2015) The Heavy Metals in Agrosystems and Impact on Health and Quality of Life. *Macedonian Journal of Medical Sciences*, 15, 3(2),345-355.

Van Diepen, C.A., Van Keulen, H., Wolf, J., Berkhout, J.A. (1991) Land evaluation: from intuition to quantification. *Advances in Soil Science*, 15, 139–204.

Vandermeer, J. H. (2011). *The ecology of agroecosystems*. Jones & Bartlett Publishers, Canada, 6339 Ormindale way, Mississauga, Ontario, L5V 1J2, Canada, 387pp.

Vibrans, H. (1998) Native maize field weed communities in southcentral Mexico. *Weed Research*, 38, 153–166.

Wiłkomirski, B., Sudnik-Wójcikowska, B., Galera, H., Wierzbicka, M., Malawska, M. (2011) Railway transportation as a serious source of organic and inorganic pollution. *Water, Air, & Soil Pollution*, 218, 333-345.

Zahran, M. A., Willis, A. J. (2008) *The vegetation of Egypt* (Vol. 2). Springer Science & Business Media.

Zhang, W., Ricketts, T.H., Kremen, C., Carney, K., Swinton, S.M (2007) Ecosystem services and dis-services to agriculture (2007) *Ecological economics*, 64(2), 253–60. https://www.sciencedirect.com/science/article/abs/pii/S0921800907001462

Zohary, M. (1966) *Flora Palaestina*. Part 1: Text Equisetaceae to Moringaceae, 2nd ed. Israel Academy of Sciences and Humanities: Jerusalem, Palestine, ISBN 9789652080004. 2

Zohary, M. (1972) *Flora Palestina*. Part 2: Text Platanaceae to Umbelliferae; Israel Academy of Sciences and Humanities: Jerusalem, Palestine.