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Comparative view for the impact of five eco factors on species distribution and weed community structure in Isthmus of Suez and adjoining farmland east Nile delta, Egypt

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ABSTRACT

The study of the extent of variability and the order of importance for the impact of environmental factors on species distribution and weed community structure from one region to the other is an interesting research subject. The present study aimed to discuss the issue to give a comparative view with the author's findings about the impact of the prevailing climate, soil type, crop type, crop sustainability and urbanization on species distribution and weed community structure in the coastal farmland and adjacent territories in northwest delta region (Mahgoub, 2019). A new sample area selected and comprised the reclaimed land of El Ballah region in Isthmus of Suez and adjoining farmland east Nile delta. A total of 245 species were recorded. Agglomerative Hierarchical Clustering (AHC) identified four vegetative sociation groups (VSG). The diversity of the four identified VSG or weed communities was evaluated at different levels. Parincipal Component Analysis (PCA) indicated the influence of the five eco factors on species distribution and variability of weed community structure, summarized the relationships among variables and investigated the proximity among samples and how they related to variables. ANOVA followed by Tukey's test were applied twice for the resulted VSG, one depending on soil variables as explanatory variables and the other on sampling site's indicative scores for the five eco factors. The results of ANOVA (R^2, F, P), sample variance (S^2) and other multivariate analyses indicated a different order of importance for the impact of the five eco factors in comparable to the former study denoted above. The soil type was the most impacting factor on species distribution and weed community structure, followed by crop type, crop sustainability, prevailing climate and urbanization, respectively.

1. Introduction

The study of the extent of variability and order of importance for the impact of environmental factors on species distribution and weed community structure from one region to the other is an interesting research subject. In a previous research on coastal farmland and adjacent territories in Northwest Delta region, the author determined the extent of variability and order of importance for the impact of five environmental factors on species distribution and weed community structure (Mahgoub, 2019). It was concluded that the heavy rainy winters caused a remarkable increase of the total species richness γ-diversity, Whittaker. Also, this prevailing climate was the most impacting factor on species distribution and weed community structure followed by urbanization, crop type, soil type and crop sustainability. It is obvious that, the plant community structure in an area is the most sensitive indicator of climate. But you cannot point to one single eco factor responsible for biodiversity of communities or diversity of weed communities or vegetative sociation groups (VSG) or even for a community. You can say, however, that weed communities or vegetative sociation groups (VSG) are determined by the combined effects of several eco factors and it could be expected that an ecological factor may be the dominant in determining the vegetation structure in a certain region and co-factor in another one depending on the available natural resources (Mahgoub, 2019). The structure of weed communities is affected by many factors as farm management practices (Derksen et al., 1994; Andersson and Milberg, 1998; Thomas and Frick, 1993), crop type (Andersson and Milberg, 1998; Andreasen and Skovgaard, 2009), seasonality (El-Demerdash et al., 1997; Mahgoub, 2017) and soil characteristics (Fried et al., 2008; Pinke et al., 2010). The many

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factors involved in the formation of the weed community make it difficult to evaluate the relative importance of each individual factor (Pyšek and Leps, 1991). However, it is also expected to find that the prevailing climate, soil type, crop type, crop sustainability and urbanization are usually the main drivers for the variability in species distribution and weed community structure from one area to the other. The issue was emphasized throughout the results of several ecological researches. Andersson and Milberg (1998); Milberg and Andersson (1998); Menalled et al. (2001); Walther et al. (2002); Andreasen and Skovgaard (2009); Hanzlik and Gerowitt (2011); Cho et al. (2015) and Mahgoub (2017); revealed that the significance of local site characteristics such as abiotic factors (soil and climate) and management practices for the occurrence of single species, community composition and species richness, are profound. Holzner (1978); Kowarik (1990), 1995; Palmer et al. (1999); Czech et al. (2000); Stein et al. (2000); Blair (2001); Firehun and Tamado (2006) and Leon et al. (2017) indicated the main effect of the other three eco factors (crop type, crop sustainability and urbanization) on species distribution and community structure. However, the current research topic has not been adequately addressed. The present study aimed to give a comparative view for the impact and the order of importance of the formerly mentioned five eco factors as to aid in developing a beneficial sustainable concept of weed control strategy. The selected sample area for the present study comprised the reclaimed land in Isthmus of Suez (El Ballah region) and adjoining farmland of East Delta, Egypt. This man-made habitats as in the case of reclaimed desert lands represent species-rich environments (Wittig, 2002) and within such habitat heterogeneity the frequent and diverse disturbances creating mosaics of different successional stages and immigration of alien species, resulted (Pyšek et al., 2002). Thus, this human interference caused the weedy species to replace the wild plant species in these reclaimed areas (Baessler and Klotz, 2006). These invasive species in the new agricultural lands cause serious problems that require attention to be paid to the negative impacts of plant invasions on ecosystems and gene pools (Hegazy et al., 1999). In fact, understanding the combined impacts of different drivers of change on vegetation is a particular challenge. For this reason, the research considered various analyses for assessing vegetation changes in response to the five eco factors under study. Through the work of several ecologists (Streibig, 1979; Andreasen et al., 1991; Salonen, 1993 and Kenkel and Orlóci, 1986, 2002), it was obvious that the employment of numerical methods and multivariate techniques is a useful tool to show the relationships between spatial distribution of weed species and different ecological habitats. It is also evident that the analyses of spatial variation in multispecies weed communities together with environmental factors are beneficial for developing a sustainable long term weed control and soil management strategy.

2. Methodology

The following procedures carried out according to the same methodology described in the author's previous research (Mahgoub, 2019). The main reason of such conduct is to verify a comparable view for the extent of variability and order of importance for the impact of the five eco factors on species distribution and weed community structure in different regions.

2.1. The study area

The study area is a trapezoid with an area of 1700 km^2. Its west side located in Ash Sharqia or EL-Sharqia Governorate while its east side located in Ismailia Governorate. The west side is about 40 km length from Faqus (Ash Sharqia province, coordinates: Latitude: 30.720058 | Longitude: 31.801453) and extending northwards to Tanis or San al-Hagar el-Qebleyah (coordinates: Latitude: 30.952808 | Longitude: 31.896889) and the east side is about 20 km length from El-Ballah region in Isthmus of Suez (coordinates: Latitude: 30.751042 | Longitude: 32.324579) and extending northwards to El-Qantara Gharb (Ismailia province, coordinates Latitude: 30.850491 | Longitude: 32.301441), and about 60 km width in between the two sides, see Fig. 1.

The Meteorological records of the area were obtained as a courtesy from the Egyptian Meteorological Authority (EMA). They included records of the monthly averages of rainfall (mm), temperature (°C), relative humidity and evaporation from four stations from 1960 to 2017.

The chemical and mechanical analyses are those quoted from the records of Ministry of Agriculture and Land Reclamation (MALR), Department of soil survey, Egypt; for respect of its authority and farmers property. The reports included the analyses of soil samples of localities or stands (villages). As each of the sampling sites (districts) contained several localities (villages), the weighted average has been calculated to express the soil properties which dominate a sampling site. The depth of soil horizon profiles were 0–30, 30–60, 60–90, 90–120 cm; in them the following soil properties were measured: 1) soil texture expressed as percentage for clay, silt, clay + silt, fine sand, coarse sand, 2) Water holding capacity (100 g soil %), 3) Hydrolytic conductivity (cm./hour), 4) Soil reaction (PH), 5) Salts in water saturated soil extract: for cations (Ca, Mg, Na, K), and for anions (CO3, HCO3, Cl), 6) Total soluble salts (%) and 7) Calcium carbonate content (CaCO3). The values of separate % for clay, silt and sand of the localities and sampling sites were applied in a soil texture triangle Fig. 3 and the identified four vegetative sociation groups (VSG) superimposed on sample points. It should be also pointed out that the soil type identified is in terms of soil texture, according to USDA soil taxonomy (USDA classification system, 1999, 2006).

2.2. Field sampling design and data collection

Stratified sampling technique (Müller-Dombois and Ellenberg, 1974: pp. 177–209) was used as an ecological sampling design method. Accordingly, within the administrative boundaries of each governorate, number of samples or sampling sites (districts) were randomly selected in each transect. But these allocating samples were deliberately to each of the recognized different ecological habitats. These samples (10 sampling sites) have represented farmland in the different ecological habitats that have been recorded in the surveyed area. These habitats were: reclaimed land in Al Ballah region and adjoining territories in East Delta region; old cultivated land in East Delta region and those at the fringes of salt marshes. Within the administrative boundaries of each sampling site (district), five localities (villages or stands) were designated (a total of 50 localities). In each locality (stand), field plots (*relevés*) for the cultivated crops were surveyed, each of which 1000–1500 m^2. The field plots in the georeferenced 10 sampling sites were visited regularly and the associated species recorded. The presence of species was taken to indicate degree of ecological success and sociological performance. The records of plant life in each field also included notes on phenology (timing of life cycle events e.g. flowering, fruiting, … etc.) and characterization of margin species that seemed to be frequently observed outside boundaries of the cultivated fields (in general water-channels, canal-banks and the irrigation/drainage network canals). The presence of species was recorded in different seasons through sequential seasonal excursions during year 2017. The sampling sites visited 6 times; three visits during the winter half of the year from December to May (in January, March and April) and the other three visits in the summer half of the year from June to November (in June, August and September) to follow the frequencies of weeds, their spatial distribution and their seasonal aspects.

During the winter half of the year 305 field plots (relevés) were surveyed and during the summer half 299 field plots were surveyed. In

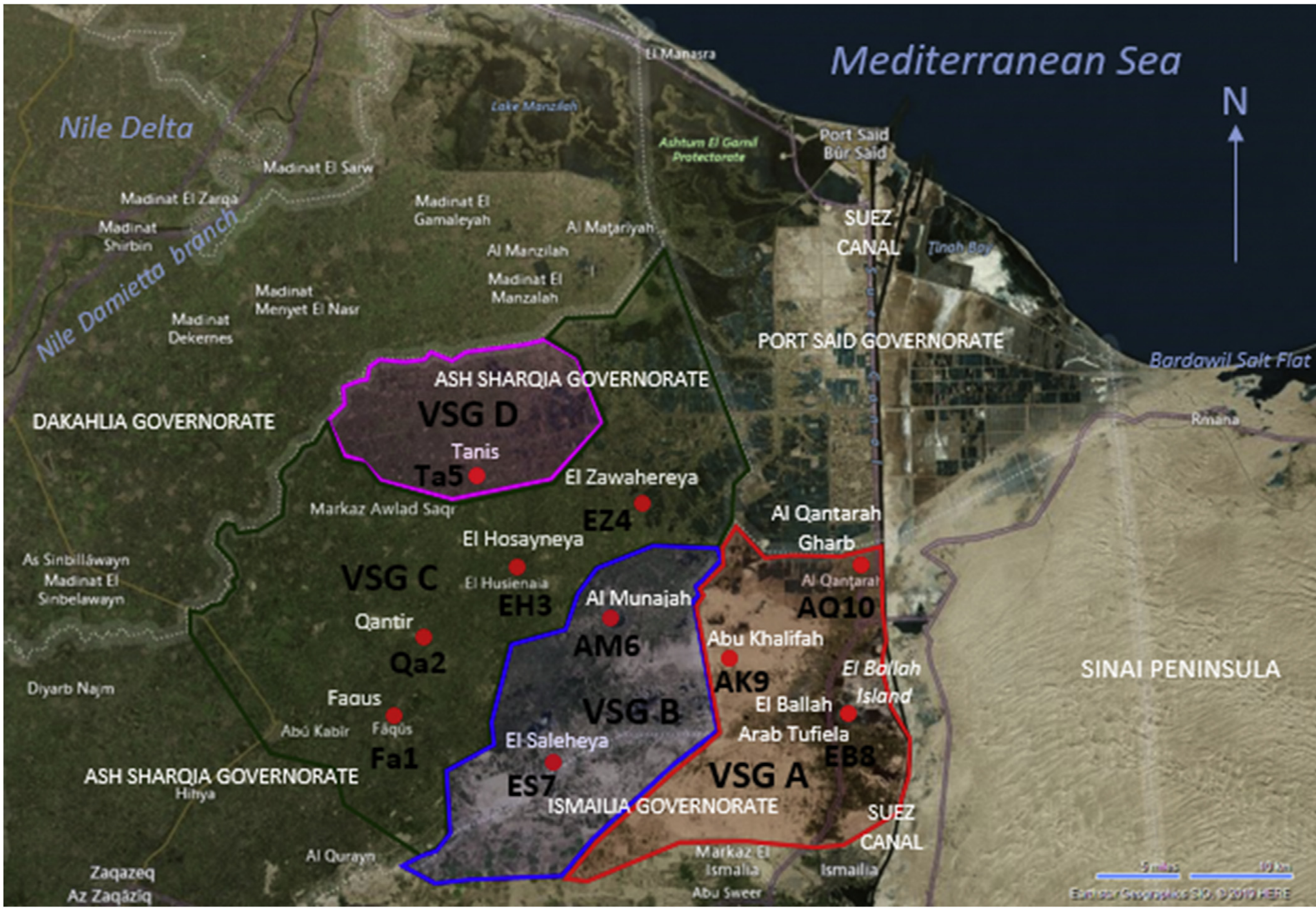

Fig. 1. Location Map of the surveyed area; within the administrative boundaries of each of the monitored ten sampling sites (districts), 5 localities (villages) were selected, in each of them number of field plots (*relevés*) were surveyed as to represent the various farmland in the different ecological habitats. The boundaries of the four weed communities or VSG (A–D) were superimposed on the map (for legend of sites, see Fig. 3). "Map adapted from Bing Maps. Microsoft product screen shot(s) reprinted with permission from Microsoft Corporation. © 2019 Microsoft".

Table 1
Methodology and Mathematical formulation of the measured species importance values.

Measured Item	Symbol	Methodology and Mathematical formulation
Recurrence index percentage	RI%	$RI\% = \frac{\text{number of fields in which a species was recorded in sampling site}}{\text{total number of fields surveyed in sampling site}} \times 100$
Average of RI%	ARI%	$ARI\% = \frac{\text{sum of RI\%}}{\text{number of sampling sites in which a species was recorded}}$
Record of species	R	R = *number of sampling sites in which a species was recorded*
Winter recurrence index %	WRI%	WRI% = *average of species wri%, where* $wri\% = \frac{\text{number of fields in which a species was recorded during winter half of the year in a sampling site (December – May)}}{\text{total number of fields surveyed in a sampling site}} \times 100$
Summer recurrence index %	SRI%	SRI% = *average of species sri%, where* $sri\% = \frac{\text{number of fields in which a species was recorded during summer half of the year in a sampling site (June – November)}}{\text{total number of fields surveyed in a sampling site}} \times 100$
Seasonal aspect of species (or Species Seasonality)	SS	*Described as "A, W, Ws, S, Sw" according to the following formulations:*
All-the-year-round weeds	A	A *if* WRI% = or ≈ SRI%
Winter weeds	W	W *if* WRI% ≥ 2 SRI% or WRI% higher than the yearly RI%
Early-appearing winter weeds	Ws	Ws *if* WRI% ≥ 2 SRI% or WRI% higher than the yearly RI% & sp.record in summer half of the year ≥ ¼ of its yearly RI%.
Summer weeds	S	S *if* SRI% ≥ 2 WRI% or SRI% higher than the yearly RI%
Early-appearing summer weeds	Sw	Sw *if* SRI% ≥ 2 WRI% or SRI% higher than the yearly RI% & sp. record in winter half of the year ≥ ¼ of its yearly RI%.
Seasonal bias percentage	Sb%	Sb% = *average degree of its seasonal bias calculated as percentage* Sb% = WRI% - SRI% = - (biased to the summer half of the year 0 (not biased) + (biased to the winter half of the year) *(+ and – values represent the degree of seasonal bias to the winter or to the summer respectively and closer bias values to zero indicated a less significant bias for the species than others that had higher values and 0.0 means not biased).*
Crop record	CR	CR = *the number of agroecosystems in which a species was recorded in the surveyed area.*

these field plots a total of 16 agroecosystems including croplands and orchards were monitored. The number of agroecosystems monitored differs from one sampling site to the other, it ranged from 8 to 15. The 16 agroecosystems were classified into categories according to their seasonality into: five winter crops (sown in Autumn and harvested in early Summer), six summer crops (sown in Spring and harvested in Autumn) and five orchard crops. These crops included: Clover (*Trifolium alexandrinum* L.), Broad bean (*Vicia faba* L.), Tomato (*Solanum lycopersicum* L.), Wheat (*Triticum aestivum* L.), Flax (*Linum usitatissimum* L.), Cotton (*Gossypium barbadense* L.), Maize (*Zea mays* L.), Rice (*Oryza sativa* L.), Peanut (*Arachis hypogaea* L.), Watermelon (*Citrullus vulgaris* Schrad.), Sweet-melon (*Cucumis melo* L.), *Citrus* (*Citrus sinensis* (L.) Osbeck., *Citrus reticulata* Blanco and other cultivated *Citrus sp.*), Guava (*Psidium guajava* L.), Mango (*Mangifera indica* L.), Olive (*Olea europaea* L.) and Pomegranate (*Punica granatum* L.). The raw data sets were summarized in a final data table for species *versus* sites (Appendix 1). The table included two main categories of information: the species performance in the 10 sampling sites and their performance in winter crops, summer crops and orchards. The performance of species in each of the 10 sampling sites was indicated by determining its recurrence index percentage (RI%) and three other importance values which are: its life span (*ls*), winter recurrence index (*wri*%), summer recurrence index (*sri*%). To determine species ecological success among the surveyed area the following items were calculated from the raw data, as well: ARI%, R, LS, SS (being described as A, W, Ws, S, Sw) and Sb%. The methodology and mathematical formulation for the measured items were presented in Table 1. It should be pointed out that (Ws) and (Sw) represent species which showed some tangible growth in the corresponding other half of the year ($\geq$¼ % of their total records). These early-appearing winter weeds (Ws) started their growth before the end of the summer half of the year or from the beginning of Autumn while the early-appearing summer weeds (Sw) started their growth before the end of the winter half of the year or from the beginning of spring. The above rules can't be strict rules as the records of species vary from year to year, as climatic factors do; they also related to their seasonal aspects, life span, phenology and the likely association between the cultivated crops and weed assemblages.

To describe the performance of species in the 16 agroecosystems monitored in the surveyed area, the number of agroecosystems in which a species was recorded (CR) has been calculated. In addition, the relative abundance of species in the three categories of agroecosystems was determined: for winter crops (CW), for summer crops (CS) and for orchards (CO). These abundance values were rounded to their integers and expressed in a simple somewhat subjective scale consisting of a series of numbers from 1 to 5 and a plus sign as follow: 5 (very common, 80–100%), 4 (common, 50–79%), 3 (Frequent, 20–49%), 2 (Occasional, 10–19%), 1 (rare or scarce, 5–9%) and + (very rare, >0–4%).

To indicate the variability in species performance and the likely association of species with certain sampling sites in certain agroecosystems, the maximum records of species were highlighted with bold text values. The last column related the recorded species to the identified vegetative sociation groups (VSG, A-D) and the bold denoted the dominant species in VSG. The margin species were marked by * (asterisk) and an empty figure means that the species was not recorded. It should be noted that the tree species were recorded as saplings within crop fields, and they were eventually removed through weeding.

To give an insight about the effect of seasonality on the floristic composition in each sampling site the rate of weed seasonality was calculated = the difference between number of species recorded in the winter half of the year and those recorded during the summer half (absolute value).

The indicative scores of the five environmental factors (prevailing climate, soil type, crop type, crop sustainability and urbanization) were calculated for each sampling site and deposited at the end of respective column. These parameters were used to measure the impact of the five eco factors on species distribution and weed community structure during multivariate analyses. The following concepts were accepted to represent the sampling site's indicative scores. Number of species which belong to Mediterranean element either pure or with extensions into other territories calculated as percentage relative to total number of species recorded, as a measure of the extent of the impact of the Mediterranean climate on vegetation as a prevailing climate in the area under study. Number of identified soil type calculated as percentage of total number of recorded soil types in terms of soil texture according to USDA soil taxonomy, to measure impact of soil type. Number of cultivated crops and number of cultivated orchards calculated as percentage of total number of agroecosystems monitored, to measure impacts of crop type and crop sustainability, respectively. Number of introduced species to the area calculated as percentage of total number of species recorded in site's group (VSG) was accepted as an indirect measurement for the degree of human disturbance and effect of urbanization on vegetation structure. The previous concept of “the Number of introduced species to the area” expresses the number of new recorded species in the study area compared to those species collected during Täckholm's time and deposited as Herbarium specimens in *Cairo University Herbarium* (*CAI*). From 1926 where Täckholm and her collaborators had started to collect information about the Egyptian wild flora to launch a project to establish the nucleus of the present Herbarium until fifties of the 20th century where "*Flora of Egypt*" has begun to appear.

The chorotype abbreviations are those applied by Wickens (1976). The Botanical Nomenclature of the recorded species have been updated from that appeared in the checklists of Täckholm (1974) and Boulos (2009) to a more recent Plant List, created by the Collaboration between the Royal Botanic Gardens (Kew), Missouri Botanical Garden (MO) and other collaborated institutions (Version 1.1, September 2013). It is an Internet encyclopedia project launched in 2010 to compile a comprehensive list of botanical nomenclature which provides an accepted Latin name for most species, with links to all Synonyms by which that species has been known. Accordingly, the Nomenclature of the plant species have been updated to the names denoted by “Accepted” in the list, if available, or the Synonym that match an assessment of medium to high confidence level. Voucher specimens of each recorded species were collected and identified earlier in *Cairo University Herbarium* (*CAI*), where they deposited as Herbarium specimens and numbered by a serial collecting number (*MAHGOUB'S collecting number*).

2.3. Diversity and multivariate analyses

During Multivariate Analyses (MVA), the following software were used: Vegan packages (Oksanen et al., 2013) in R environment (version 3.2.3, 2015), IBM SPSS Statistics ver.22 (2013) and XLSTAT (2015). Agglomerative Hierarchical Clustering (AHC) was employed as a clustering technique using Euclidean distance as a measure of dissimilarity and Ward's method (Minimum-variance clustering) as an agglomeration criterion (Orlóci, 1978). It was used to classify the sampling sites based on the variation in their floristic composition into groups and the Center/Reduce option selected to avoid having group creation influenced by scaling effect. The sites were ordered first and then the species were clustered based on the classification of sites. The four identified weed communities or the 4 vegetation sociation groups (VSG A - D) were named after the two most dominant species in each group in light with the conclusion that a plant community type is defined by the dominance of one or more species and these species are usually the most important ones in the uppermost stratum of the plant canopy (Whittaker, 1962). The diversity of the identified VSG has been measured and evaluated at different levels to estimate the extent of variation in their vegetative structure. The following diversity indices were estimated (including Alpha (α) and *Beta* (β) diversity): Species richness (S) “*Taxa_S*”; Shannon-Wiener diversity index (H) “Shannon_H”; Equitability (E) “Equitability_J”; Dominance (D) “Dominance_D” and Beta (β) diversity (βw). Table 2 captures their mathematical formulations and their sources.

Table 2
Mathematical formulation and source of the measured Diversity Indices.

Measured Item	Symbol	Mathematical formulation and source
Species Richness (S), "Taxa_S"	S	*Number of taxa (S) in a sampling site and for VSG counted as the average number of species per VSG's sampling sites.* (Magurran, 2004, see also Chao, 2005).
Shannon-Wiener diversity index (H), "Shannon_H"	H	$H = -\sum_{i=1}^{S}(P_i * lnPi)$ *where H is the Shannon diversity index, Pi = fraction of the entire population made up of species i, S = numbers of species encountered, $\sum$ = sum from species 1 to species S and ln is a natural logarithm of the number.* (Shannon and Weaver, 1949, see also Pielou, 1975; Vidakovic, 2011).
Equitability (E), "Equitability_J"	E	$E = \frac{H}{lnS}$ = *Shannon diversity (H) divided by the logarithm of number of taxa (S)*, (Hill, 1973, see also Harper, 1999)
Dominance (D), "Dominance_D"	D	D = *1-Simpson index*, $D = sum(ni/n)^2$, *where ni is number of individuals of taxon i and n is the total number of individuals.* (Simpson, 1949, see also Harper, 1999).
Beta (β) diversity	βw	$\beta w = \frac{S}{\bar{\alpha}}$, *where S = the total number of species recorded in the system (i.e. γ diversity); α = the average sample diversity; which is measured as species richness found within the samples* (Whittaker, 1960, see also Magurran, 2004; Lande, 1996; Koleff et al., 2003).

Principal Component Analysis (PCA, Hotelling, 1933; Jolliffe, 2002) was used to get a view for the influence of the five variables (environmental factors or eco factors) on species distribution and variability of weed community structure for the identified VSG, summarize the relationships among variables and investigate the proximity among samples and how they relate to variables. The data were standardized prior to the analysis and Pearson (n)/PCA was used. The variables analyzed during PCA were the five eco factors, rate of weed seasonality and diversity indices. The four resulted VSG (A-D) have been superimposed upon the sample points (sites) and convex hulls have been drawn in the resulted PCA biplot to confirm the validity of the segregation into four groups.

The fourth identified group (VSG D) which comprised one sampling site (Ta5) was excluded from ANOVA test as it violated the assumptions of the test (i.e. criteria). However, the mean values of its explanatory variables were mentioned aside to ANOVA table for group comparison. The other three identified groups (VSG, A - C) were subjected twice to Analysis of Variance (ANOVA) followed by Tukey's test (HSD). The first of which was depending on soil properties as explanatory variables and the second was depending on the indicative scores as explanatory variables. The coefficient of determination (R^2) was determined and Tukey's test (HSD) applied to significant variables in both analyses. The data of the indicative scores of sites for the five environmental factors were standardized and the sample variance (S^2) has been calculated from the following formula: $S^2 = \sum(x_i - x)^2/n\text{-}1$, where S^2 is sample variance, $\sum$ is sum, x_i is the term in data set (indicative scores of sites), x is sample mean, and n is sample size.

The results of ANOVA (R^2, F, P), the sample variance (S^2) and the other multivariate analyses have been taken to express for the impact of the five eco factors and their order of importance, on species distribution and weed community structure in farmland of the surveyed area.

3. Results

3.1. Environmental factors

The prevailing climate

The meteorological records provided from the Egyptian Meteorological Authority (EMA) of four climatic stations in the two governorates from 1940 to 2017 express the general attributes of rain fall in arid regions. The climate characterized by low annual rainfall, brief rainy season (winter: November–April) and long rainless season (summer: May–October). The climatic data during year 2017 showed that the area was exposed to some light rain at different times of the winter. The northern sites (Ta5, EZ4, AQ10) had received twice the amount of rainfall compared to the central and southern areas where the rainfall was erratic. The records also showed that the evaporation rates in July and August are lower than in June and this relates to the consistently higher humidity in those of the late summer months as compared to the earlier summer months May and June. Fig. 2 presents the prevailing climatic conditions in year 2017 where main winter rain extended from November to March and summer was almost rainless. The winter was warm and minimum temperature records didn't reach freezing and the summer was hot.

Soil type

The analyses of soil samples of the localities (villages) which belong

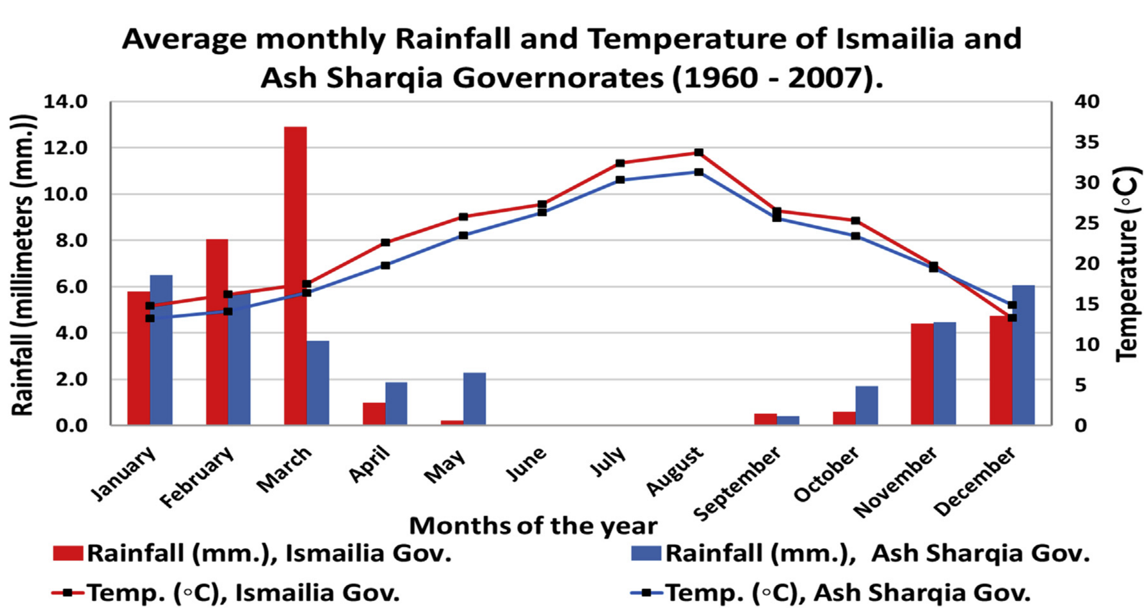

Fig. 2. Climate Graph for the surveyed area (2017).

to the 10 sampling sites (districts) had indicated that four principal soil groups could be defined: (1) clay soils that range from well drained clay soils to poorly drained clay soils and swamps and clay flats, in the north toward Lake Manzala; (2) cultivated Nile Delta clay-and-silt soils in the west; (3) loose sands and windblown sands in the east part and extends to the middle and south parts and (4) patches of gravelly or gritty sandy soils of deltaic stage of river terraces. It should be noted that in some farmland in the villages (localities) of northern sampling sites in Ash Sharqia Governorate (e.g. the village of Geziret Saud in Al Munajah district (AM6)) the ground level is elevated forming patches or sand islands; which organize into an arch of high land. They consist of sand, gravel, sandy clay and silt. In terms of soil texture and according to the USDA - soil taxonomy classification system which uses 12 textural qualitative classes (Soil taxonomy: A Basic System of Soil Classification for Making and Interpreting Soil Surveys, Soil Survey Staff, 1999); eight soil texture types were defined in the surveyed area: clay soil, clay loam, loam, loamy sand, sandy clay, sandy clay loam, sandy loam and sandy soil (refer to Fig. 3). Of these, up to five soil types were defined in each site. But in general, the measurement of the weighted average indicated that clay and loam soil dominate the main bulk of the western part of surveyed area (farmland in East Delta region) while sand soil dominate its eastern part (El Ballah region of Isthmus of Suez).

Crop type and crop sustainability

Records in the 10 sampling sites revealed that the types of cultivated crops are structured by soil types and amount of cultivated crop is dependent on the available natural resources. The cultivation of sand soil crops was preferable in reclaimed land of El Ballah region, while cultivation of crops which require clay and loam soil dominated farmland of adjoining East Delta region. The number of cultivated crops recorded in sampling sites varied from 8 to 15 crops (refer to Appendix 1). The highest number was recorded in AM6 (VSG B) and AQ10 (VSG A) and the latter had scored the highest value of crop sustainability as well.

Urbanization

The number of introduced species in the area was 46 species. The records of these species in each sampling site indicated that the number of them was very low and did not exceed 8 species. The most affected sites were the coastal sampling sites facing Suez Canal in El Ballah region in Isthmus of Suez (VSG A). The measurement of the sample variance (S^2) of the site's indicative score for the parameter also had indicated that it was the least among the eco factors under study.

3.2. Species distribution

A total of 245-plant species was recorded, they include specific and infraspecific taxa (8 species). They belong to 41 families (32 Eudicots, 8 Monocots and one Pteridophyte) and included 151 genera (Table 3). The chorological analyses presented in Table 4 (a & b) revealed that the recorded species fell under 16 chorotypes and more than half of them were Mediterranean species (≈63%) either pure (40 *sp.*) or with extensions in other territories (114 *sp.*). It was observed as well that the Mediterranean element was well represented in all the identified VSG (A-D) and with convergent ratios. The results of the seasonality analysis indicated that about half of the recorded species in the surveyed area were winter weeds (W + Ws) and most of them from annuals. The results also indicated that the rate of weed seasonality usually scored high positive values to the winter season in the sampling sites where sand soil

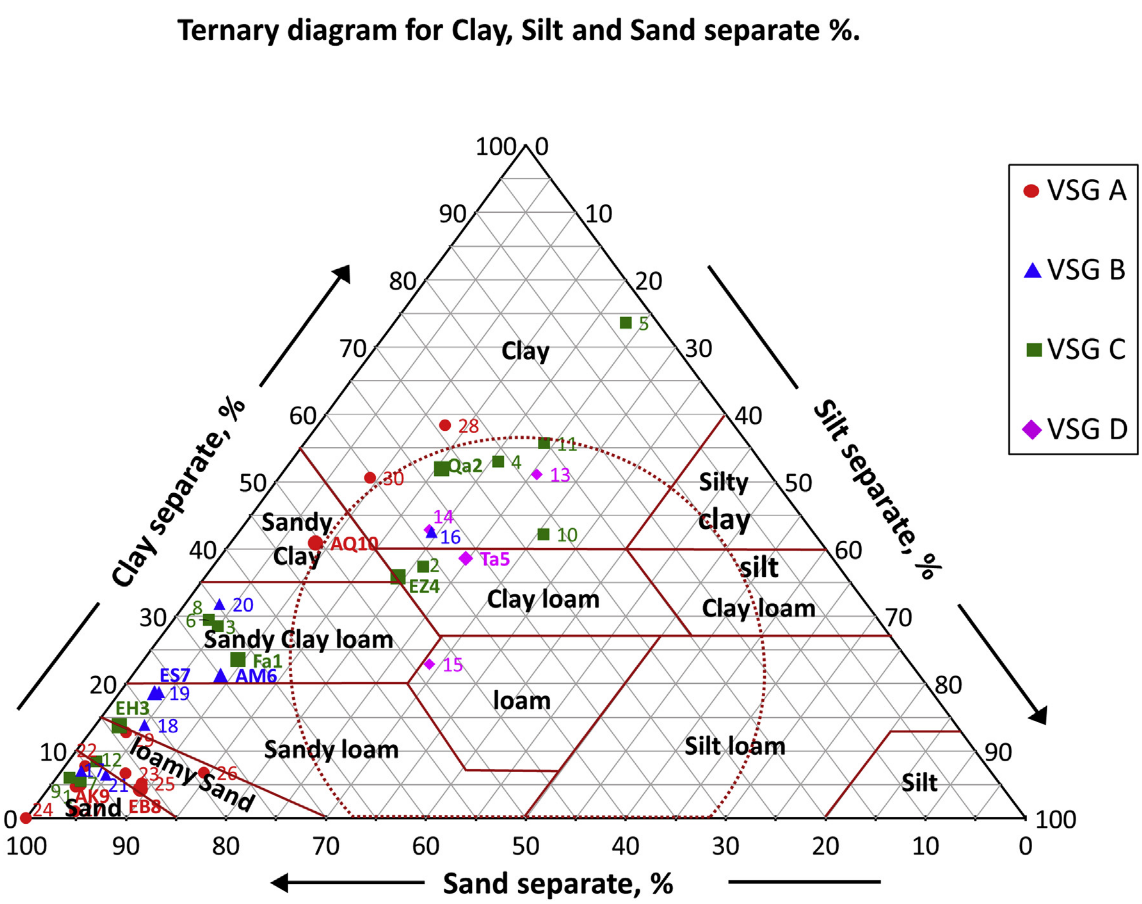

Fig. 3. Soil texture triangle showing the classification of the 10 sites and their localities according to USDA soil taxonomy. A- D are the four clusters i.e. VSG (A–D) or vegetative sociation groups resulted from AHC analysis. **Legend for sites and samples (localities):** Faqus (Fa1, 1-3); Qantir (Qa2, 4-6); El Hosayneya (EH3, 7-9); El Zawahereya (EZ4, 10-12); Tanis "San Al Hagar" (Ta5, 13-15); Al Munajah (AM6, 16-18); El Saleheya (ES7, 19-21); El Ballah "Arab Tufiela" (EB8, 25-27); Abu Khalifah (AK9, 22-24); Al Qantarah Gharb (AQ10, 28-30).

Table 3
Families recorded in the surveyed area. Figures represent number of genera included in each family (Gen.) and the total number of species belonging to each family, calculated as absolute number (Sp.) and relative number (Sp.% = %of the total number of species recorded in the surveyed area).

Family Name	Gen.	Sp.	Sp. %
Poaceae Barnhart	30	51	20.8
Asteraceae Bercht. & J.Presl	22	32	13.1
Amaranthaceae Juss.	14	23	9.4
Fabaceae Lindl.	11	20	8.2
Cyperaceae Juss.	6	12	4.9
Brassicaceae Burnett	6	11	4.5
Caryophyllaceae Juss.	6	10	4.1
Plantaginaceae Juss.	4	8	3.3
Convolvulaceae Juss.	4	7	2.9
Malvaceae Juss.	4	5	2.0
Polygonaceae Juss.	4	5	2.0
Apiaceae Lindl.	3	4	1.6
Euphorbiaceae Juss.	2	5	2.0
Solanaceae Juss.	2	4	1.6
Hydrochaiitaceae Juss.	2	3	1.2
Lamiaceae Martynov	2	3	1.2
Aizoaceae Martinov	2	2	0.8
Araceae Juss.	2	2	0.8
Onagraceae Juss.	2	2	0.8
Verbenaceae J.St.-Hil.	2	2	0.8
Juncaceae Juss.	1	5	2.0
Orobanchaceae Vent.	1	5	2.0
Tamaricaceae Link	1	5	2.0
Boraginaceae Juss.	1	2	0.8
Apocynaceae Juss.	1	1	0.4
Ceratophyllaceae Gray	1	1	0.4
Cleomaceae Bercht. & J.Presl	1	1	0.4
Gentianaceae Juss.	1	1	0.4
Lythraceae J.St.-Hil.	1	1	0.4
Marsileaceae Mirb.	1	1	0.4
Nitrariaceae Lindl.	1	1	0.4
Oxalidaceae R.Br.	1	1	0.4
Papaveraceae Juss.	1	1	0.4
Pontederiaceae Kunth	1	1	0.4
Portulacaceae Juss.	1	1	0.4
Potamogetonaceae Bercht. &	1	1	0.4
Primulaceae Batsch ex Borkh.	1	1	0.4
Santalaceae R.Br.	1	1	0.4
Typhaceae Juss.	1	1	0.4
Urticaceae Juss.	1	1	0.4
Zygophyllaceae R.Br.	1	1	0.4
Total number = 41	151	245	100

dominated and land reclamation was widely recorded. This rate decreases in the old cultivated land and unlike all sampling sites the site of Tanis (Ta5, VSG D) scored negative value for the parameter. The records of the performance and spatial distribution of weeds deposited in Appendix 1 revealed that 36 species out of the 245 recorded species were classified as high constancy weed species (Class I), 30 as moderately high constancy weed species (Class II), 42 as intermediate constancy weed species (Class III), 46 as low constancy weed species (Class IV) and 91 as rare constancy weed species (Class V). The 36-species which were classified as high constancy weed species were the most widespread in the surveyed area and they included three omnipresent species: *Cynodon dactylon*, *Sonchus oleraceus* and *Convolvulus arvensis*. The first two species were more common than the third one and each represents one of the two most dominant species of VSG B and VSG A, respectively. Although they were less affected by impact of soil type and properties than the third one which showed its best performance in the sampling sites in which sandy soil dominated, but their seasonal aspect and performance in the agroecosystems differed. The first was designated as all-the-year-round weed (A) and its seasonal bias revealed that its growth flourishes during the summer half of the year in summer crops while the other was designated as an early appearing weed in winter crops (Ws), both common in orchards. The other six dominant species of the identified four VSG (A – D) were also included in this class. Five of them had life span which extends for 3 seasons and were either Ws or Sw while the sixth was W. The rest of species included in Appendix 1 showed also a variable performance as response for impact of environmental factors. To name a few; the performance of *Brassica nigra* (class I), *Cichorium pumilum* (class I) and *Cyperus difformis* (class II) was more influenced by crop type and their highest records had been always associated with clover and rice cultivations. It can also point out that the performance of 4 species which belong to class I was more influenced by soil types and properties. These species were *Phragmites australis*, *Spergularia marina*, *Chenopodium album* and *Erigeron bonariensis.* The first two species scored their highest presence estimates in farmland at the fringes of salt-marshes and in water-saturated soils while the other two species scored their highest presence estimates in sandy soils. Furthermore, the latter was more influenced by crop sustainability and was more common in orchards than in the other agroecosystems as *Cyperus rotundus* had done. In comparable to the former performance, the growth of some species was more confined to their specific environmental conditions i.e. their own microhabitat or ecological niche. For example, *Silene behen* (class IV) was frequent in AK9 site, rarely recorded in the two other sampling sites of El Ballah region and absent in the rest of sites while *S. conoidea* (class V) restricted its rare presence in the coastal farmland facing Suez Canal in sampling sites EB8 and AK9. Upon tracing more species records and their maximums which were denoted by figures highlighted with bold text values in the five constancy classes we can find more examples elaborating the variability in weed performance.

3.3. Multivariate analyses and diversity

Based on their floristic composition, the ten sampling sites were clustered using Agglomerative Hierarchical Clustering (AHC) into four groups at a distance threshold indicated by the dotted line in Fig. 4. These four vegetative sociation groups (VSG) or weed communities are: VSG A or group *Sonchus oleraceus-Chenopodium murale* and it was distinctive for 3 sampling sites (EB8, AK9 and AQ10); VSG B or group *Cynodon dactylon-Panicum repens* and it was distinctive for 2 sampling sites (AM6 and ES7); VSG C or group *Beta vulgaris-Echinochloa colona* and it was distinctive for 4 sampling sites (Fa1, Qa2, EH3 and EZ4) and VSG D or group *Polypogon monspeliensis-Melilotus messanensis* and it was distinctive for one sampling site (Ta5). Visualizing the geometry of AHC dendrogram (Fig. 4) indicated that the cluster of VSG C was the largest in size and the chunks (sites) Fa1 and EH3 were the most similar in the clade. However, the cluster of VSG A was the more homogenous one. This was confirmed when looking at the within-class variable. It also indicated that the *bifolious* clade of VSG B was more similar in its floristic composition to VSG A while the *unifolious* clade of VSG D more like VSG C.

The measured diversity indices revealed the extent of variability in weed community structure of the four identified VSG (A-D). The highest total species richness (S) was scored by the sites of VSG A (S = 183), followed by VSG C, B, D (S = 165, 156 and 67, respectively), however, the number of species which belong to each group was; 99, 70, 45, 31. It happens very often that species have their records shared among the groups this intermingle was expected and it was accepted. Moreover, the diversity measurements showed further variation in the vegetative structure between the two vegetative sociation groups characterizing the sampling sites dominated by sandy soils (VSG A & VSG B) and between the other two which characterize those dominated by clay and loam clay soils. For the first two groups, although VSG A scored higher value of S it scored convergent values of H and D and lower value of E than VSG B. As for the other two groups, VSG C scored higher values of S, H and E and scored lower value of D than VSG D. It should be also pointed out that VSG D scored the highest D value and the lowest S, H, and E values in comparable to other groups (Fig. 5). The pairwise beta diversity index presented in Table 5 emphasized that view and showed that VSG D is highly dissimilar from all other groups and VSG B is similar in species composition to VSG A as compared pairwise more than if it is compared pairwise with VSG C (the Global β diversity (Whittaker) = 0.716).

Table 4(a)
ChorologicaLAnalyses of the Flora recorded in the surveyed area. The first two columns present the chorotypes and the total number of species which belong to each chorotype. The following columns include the numbers of: A (All-the-year weeds), W (Winter weeds), S (Summer weeds) and those which be long to the four VSG (A - D); maximum values in bold text.

Chorotypes	Total number of species		Seasonality of species							Chorological analysis for VSG			
	Sum	%	A	W	Ws	W + Ws	S	Sw	S + Sw	VSG A	VSG B	VSGC	VSG D
COSM	25	10.2%	4	6	6	**12**	6	3	9	18	17	**19**	5
PAL	29	11.8%	1	12	4	**16**	9	3	12	**21**	15	16	7
PAN	17	6.9%		6	2	8	3	6	**9**	11	11	**15**	2
Monoregional													
ME	40	16.3%	5	15	8	**23**	7	5	12	**30**	24	24	14
S-Z	2	0.8%	1	1		**1**				**2**	1	1	1
Endemic	1	0.4%						1	1	**1**	**1**	**1**	**1**
Biregional													
ME + IR-TR	48	19.6%	6	21	5	**26**	10	6	16	**39**	29	28	14
ME + SA-SI	19	7.8%	4	6	2	**8**	5	2	7	**16**	12	**16**	6
ME + ER-SR	7	2.9%		4		**4**	1	2	3	4	5	**7**	3
IR-TR + SA-SI	9	3.7%	1	4	1	5		3	3	**7**	**7**	6	5
S-Z + SA-SI	7	2.9%		2	1	3	2	2	**4**	3	2	**5**	1
S-Z + IR-TR	1	0.4%					1		**1**	**1**		**1**	
Triregional													
ME + IR-TR + ER-SR	26	10.6%	**9**	6	3	**9**	4	4	8	20	**22**	18	7
ME + IR-TR + SA-SI	9	3.7%	1	4	1	**5**	2	1	3	**8**	5	5	1
ME + SA-SI + S-Z	4	1.6%		4		**4**				2	**4**	2	
ME + ER-SR + SA-SI	1	0.4%					1		**1**		**1**	**1**	
Total number = 16	245	100%	32	91	33	124	51	38	89	183	156	165	67

Legend for Chorotypes.
COSM = Cosmopolitan, PAL = Paleotropical, PAN = Pantropical.
ME = Mediterranean, IR-TR = Irano-Turanian, SA-SI = Saharo-Sindian.
ER-SR = Euro-Siberian, S-Z = Sudano-Zambezian, Endemic.

Table 4(b)
ChorologicaL Analyses for the Flora of the surveyed area. Figures indicated number of species which belong to *Phytochoria* (floristic, phytogeographic zones, regions & Kingdoms). The first two columns present the *Phytochoria* and the total number of species which belong to each of them. The following columns include the numbers of: A (All-the-year weeds), W (Winterweeds), S (Summer weeds) and those which belong to the four VSG (A - D); maximum values in bold text.

Species/Phytochoria	Total number of species		Seasonality of species							Chorological analysis for VSG (%)			
	Sum	%	A	W	Ws	W + Ws	S	Sw	S + Sw	VSG A	VSG B	VSG C	VSG D
Mediterranean Sp.	154	62.9	**78.1**	65.9	57.6	63.7	58.8	52.6	56.2	65.0	65.4	61.2	**67.2**
Cosmopolitan Sp.	25	10.2	12.5	7	**18**	9.7	12	8	10.1	9.8	10.9	**11.5**	7.5
Paleotropical Sp.	29	11.8	3.1	13	12	12.9	**18**	8	13.5	**11.5**	9.6	9.7	10.4
Pantropical Sp.	17	6.9		7	6	6.5	6	**16**	10.1	6.0	7.1	**9.1**	3.0
Other Chorotypes	20	8.2	6.3	8	6	7.3	6	**16**	10.1	7.7	7.1	8.5	**11.9**
Total	245	100	100	100	100	100	100	100	100	100	100	100	100

Through the result of PCA we can notice that Principal Components Analysis (PCA) was successful in separating the sampling sites dominated by sandy soil type from those where clay and loamy soil type dominated (refer to Fig. 3). It also indicated that the first axis explained 44.045 % of the total variability and together with the second axis they explained 64.095%, which is a good result. However, an overlap has been detected in the convex hulls between VSG A and VSG B. The eigenvalue of F1 (first axis or PC1) was 5.726 and of F2 (second axis or PC2) was 2.606. Upon visualizing the PCA correlation biplot (Fig. 6) we can notice that the sampling sites of VSG A and VSG B gained high positive factor scores and laid out at the positive end of PC1 while most of the sampling sites of VSG C and VSG D gained negative factor scores and laid out along its negative end. Moreover, the VSG D sampling site was located at the far negative end. Also, the right-angled projections of the object points (sites), on the clay's vector, silt's vector and sand's vector in the F1/F2 map indicated that the frequencies of species in VSG C sites and VSG D site were affected by soil content of clay and silt more than affected in other sites. In comparable, they indicated that the frequencies of species in VSG A sites and VSG B sites were the more affected by soil content of sand. The length of the vectors in the correlation biplot revealed that most of the variables were well represented in the plan F1/F2 and it seems that some information might be hidden in the next factors for the variables of: prevailing climate and urbanization. Looking at the table of the squared cosines of the variables indicated that they were well linked with the third component (F3 or PC3) and the fourth component (F4 or PC4). They would best be viewed on maps F1/F3, F1/F4, respectively. The result of the analysis also showed that the first principal component correlated most strongly with crop type and crop sustainability while the second principal component correlated most strongly with soil type. Hence F1 is viewed as a measure for the impact of crop type/crop sustainability parameters while F2 is viewed as a measure of the impact of soil type parameter. The acute angles in the correlation circle between the vectors of crop type, crop sustainability, species richness (S) and weed seasonality indicated that they were significantly positively correlated with each other (r close to 1). The angles between these vectors approximate their (linear) covariance/correlation. The acute angle between soil type and crop type indicate that they were significantly positively correlated as well. The orthogonal angles between the vector of the latter variable and the vectors of Dominance_D and Equitability_J. indicate that they were not correlated (r close to 0). The obtuse angle between the vector of soil type and the vector of Equitability_J. indicates that they were significantly negatively correlated (r close to -1).

Running ANOVA and Tukey post hoc test revealed more information. The figures highlighted with bold text values which denote the maximums of mean scores of soil properties for the VSG (A – C) sites in Table 6 indicated that the sampling sites of VSG C were characterized by the

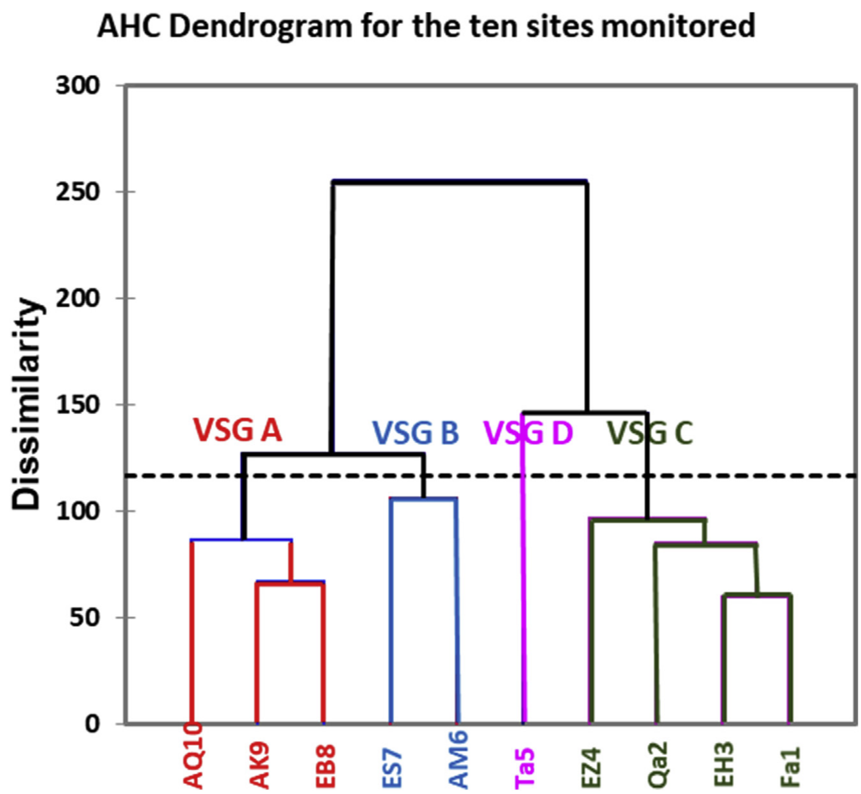

Fig. 4. AHC dendrogram for the 10 sites & the 4 VSG resulted (for sites legend, see Fig. 3).

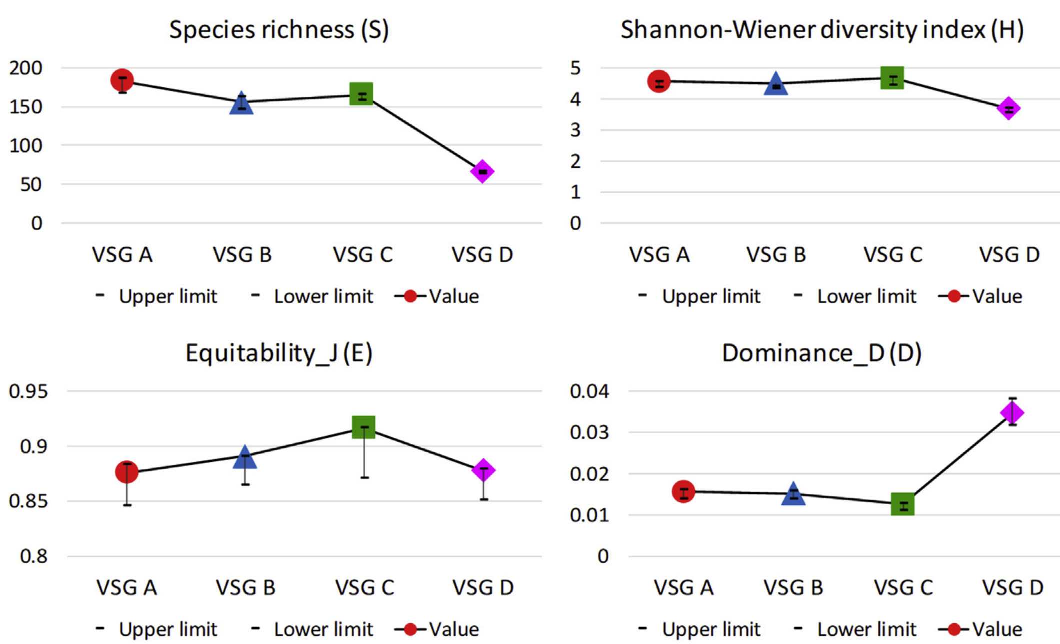

Fig. 5. Scatter charts showing the diversity indices of the 4 VSG (A–D).

Table 5
Whittaker's *Beta* (β) diversity Index for the four VSG (A-D), pairwise comparisons.

	VSG A	VSG B	VSG C	VSG D
VSG A	0			
VSG B	0.298	0		
VSG C	0.305	0.227	0	
VSG D	0.576	0.578	0.509	0

highest soil content of clay, silt, the highest water holding capacity and low values of soil salinity as in case of sampling site of VSG D. Moreover, the maximum mean scores also indicated that the sampling sites of the two other groups were characterized by a higher soil content of fine sand/coarse sand, lower water holding capacity and higher soil salinity. However, a further variability could be detected between the sampling sites of each group. As for example, the sampling sites of VSG A were characterized by the highest soil content of fine sand and high soil content for most of the measured cations and anions while those of VSG B scored the highest soil content of coarse sand, Na and HCO3. The measurement of the soil PH indicated that it was alkaline in most soil samples and the measurement of hydrolytic conductivity and total soluble salts indicated that the highest values were scored by VSG A sampling sites. Upon comparing the p-value to the significance level (P-value $\leq$: $\alpha = 0.05$) the results indicated that 3 soil variables were statistically significant. Applying Tukey's test (HSD) indicated that: fine sand significant for VSG A versus VSG B; PH significant for VSG B versus VSG A and for VSG C versus VSG A and Cl significant for A vs B.

The maximum mean of VSG sites' indicative scores in Table 7 (figures highlighted with bold text values) indicated that soil type, crop type and prevailing climate have showed their highest impact on the diversity of VSG B (weed community), in comparable with the other groups. It also

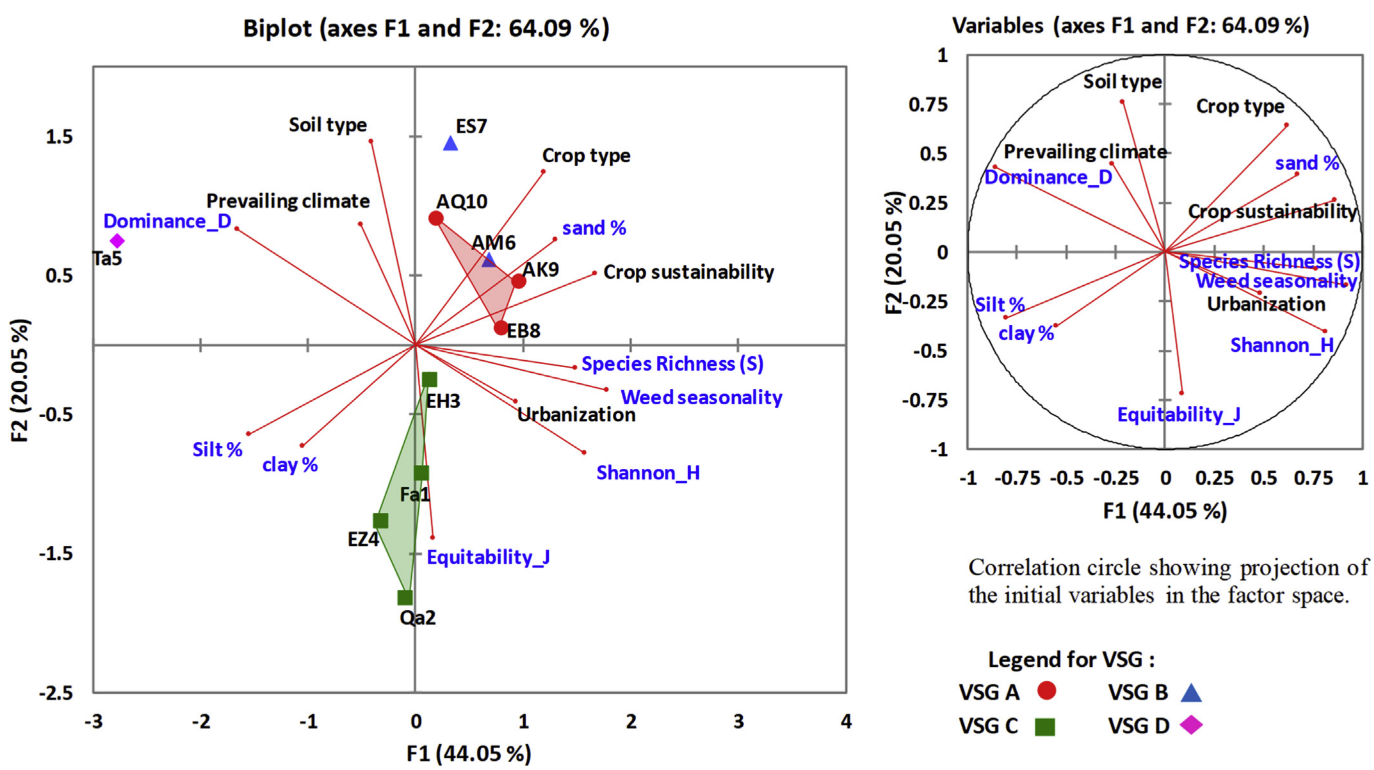

Fig. 6. Biplot representing PCA for the 10 sites and the environmental variables. The 4 VSG superimposed and the convex hulls drawn (for legend of sites refer to Fig. 3).

Table 6
"ANOVA" for the 3 VSG (A-C) depending on soil properties as explanatory variables. Group D excluded from ANOVA and placed for the comparison of group means with means of other groups. Figures included: the means ± standard errors of the soil variables for the VSG's sites (A - D; maximum in bold text), coefficient of determination (R^2), F ratio (F), P value (Pr > F) and Tukey's test (HSD). Confidence interval = 95% (P* < 0.05).

Soil Variables	Vegetative sociation Groups				R^2	F	P value (Pr > F)	Tukey's test (HSD), Cr.V. = 4.33 (Significant VSG)
	Group A	Group B	Group C	Group D				
	3	2	4	1				
clay (%)	15.5 ± 9.2	19.2 ± 11.3	**30.6** ± 8.0	**35.7** ± 15.9	0.220	0.815	0.475	No
Silt (%)	6.3 ± 3.2	6.1 ± 3.9	**11.5** ± 2.8	**22.8** ± 5.5	0.254	1.023	0.415	No
Fine sand (%)	**41.5** ± 4.9	13.2 ± 5.9	22.9 ± 4.2	31.1 ± 8.4	0.717	7.598	0.023 *	A vs B
Coarse sand (%)	29.3 ± 9.2	**57.5** ± 11.3	33.3 ± 8.0	2.8 ± 16.0	0.412	2.102	0.203	No
Water holding capacity (W.H.C., 100 gm soil %)	40.2 ± 9.8	45.5 ± 12.0	**57.4** ± 8.5	**70.6** ± 16.9	0.235	0.921	0.448	No
Hydrolytic conductivity (H.C, cm/hour)	**12.5** ± 3.9	7.0 ± 4.8	6.2 ± 3.4	0.5 ± 6.7	0.212	0.808	0.489	No
PH	7.5 ± 0.1	**8.2** ± 0.2	**8.2** ± 0.1	7.7 ± 0.2	0.775	10.331	0.011 *	B vs A; C vs A
Ca (m Eq/L)	**10.8** ± 3.6	9.2 ± 4.4	7.9 ± 3.1	**12.0** ± 6.2	0.059	0.187	0.834	No
Mg (m Eq/L)	**7.7** ± 2.3	3.7 ± 2.8	4.7 ± 2.0	6.7 ± 4.0	0.203	0.765	0.5D6	No
Na (mEq/L)	29.7 ± 10.8	**32.9** ± 13.2	26.2 ± 9.4	25.3 ± 18.7	0.029	0.089	0.916	No
K (m Eq/L)	**1.1** ± 0.3	0.5 ± 0.3	0.6 ± 0.2	0.9 ± 0.5	0.275	1.139	0.381	No
HCO3 (m Eq/L)	1.7 ± 4.4	**13.6** ± 5.3	4.3 ± 3.8	2.0 ± 7.6	0.343	1.567	0.283	No
CI (m Eq/L)	**20.0** ± 2.3	8.3 ± 2.8	15.8 ± 2.0	11.5 ± 4.0	0.635	5.217	0.019 *	A vs B
Total soluble salts [TSS, %)	**0.9** ± 0.4	0.4 ± 0.4	0.4 ± 0.3	0.8 ± 0.6	0.203	0.765	0.506	No
Calcium carbonate (CaCO3)	**5.9** ± 1.8	3.3 ± 2.2	2.1 ± 1.6	**6.9** ± 3.2	0.291	1.229	0.357	No

Table 7

"ANOVA" for the 3 VSG (A-C) depending on the 5 environmental factors and species richness (S) as explanatory variables. Group D excluded from ANOVA and placed for the comparison of group means with means of other groups. Figures included: the means ± standard errors of the enviromental variables for VSG's sites (A - D; maximum in bold text), coefficient of the determination (R^2), F ratio (F), P value (Pr > F) and Tukey's test (HSD) (P*<0.1).

Environmental Variables	Vegetative sociation Groups				R^2	F	P value (Pr > F)	Tukey's test (HSD), Cr.V. = 4.33 (Significant VSG)
	Group A	Group B	Group C	Group D				
	3	2	4	1				
Prevailing climate	64.0 ± 1.7	**65.9** ± 2.1	62.2 ± 13	**67.2** ± 3.0	0.256	1.031	0.412	No
Soil types	46.7 ± 5.1	**75.0** ± 63	35.7 ± 4.4	65.7 ± 8.9	0.515	13.17	0.006 *	B vs C; B vs A
Crop types	81.3 ± 4.5	**90.6** ± 55	60.9 ± 39	50.0 ± 7.8	0.794	11.56	0.009 *	B vs C; A vs C
Crop sustainability	**27.1** ± 1.8	25.0 ± 2.1	20.3 ± 1.3	6.3 ± 3.0	0.602	4.529	0.063 *	A VS C
Urbanization	**14.6** ± 1.5	12.3 ± 13	12.5 ± 1.3	10.4 ± 2.5	0.195	0.728	0.521	NO
Species Richness (S)	**123.0** ± 5.4	114.5 ± 10.2	104.8 ± 7.2	67.0 ± 14.5	0.314	1.376	0.322	NO

indicated that crop sustainability and urbanization showed their highest impact on the diversity of VSG A and the five environmental factors scored their least indicative scores i.e. their least impact, on the vegetation structure of VSG C sampling sites. It should be also pointed out that the indicative scores had revealed that the impact of the prevailing climate was the highest on VSG D comparable with other groups.

The measurement of the p-value indicated that 3 variables were statistically significant (P ≤ 0.01). Applying Tukey's test (HSD) revealed that: soil type statistically significant for VSG B versus VSG C, and for vs VSG A; crop type statistically significant for VSG B vs VSG C and for VSG A vs VSG C and crop sustainability statistically significant for VSG A versus VSG C. Given R^2 results, 81.5% of the variability of the dependent variable was explained by the explanatory variable for soil type; 79.4% for crop type and 60.2% for crop sustainability. It should be also noted that the values of the sample variance (S^2) of the sites indicative scores had declared that the soil type gained the highest spread-out of data points and urbanization gained the lowest spread-out while the other environmental variables earned a medium spread for data points.

4. Discussion

The Monocot family *Poaceae* Barnhart and Eudicot family *Asteraceae* Bercht., were the most species-rich lineages of the 41 families recorded in the study area. The first is nearly *ubiquitous* family and the second one is the most widespread of *Eudicot* families and probably the largest in terms of numbers of species. They have a worldwide distribution, from the polar regions to the tropics, colonizing a wide variety of ecological habitats, growing from sea-level to the highest mountain peak (Stevens, 2001). The floristic analysis revealed that more than third of the recorded species (≈34%) were Grasses and Asteraceans. Followed by ranking in terms of species richness, family *Amaranthaceae* Juss., *Fabaceae* Lindl., *Cyperaceae* Juss. and *Brassicaceae* Burnett, respectively. Together with Grasses and Asteraceans they constituted ≈61% of the recorded flora. Quézel (1978), reported that the formerly mentioned families represent the most common ones in the Mediterranean North African flora. They had been reported by the author as the largest and most widespread families in the coastal farmland and adjacent territories in Northwest Delta region (Mahgoub, 2019); as well. It should be pointed out also that the analysis showed that Graminoids made up a larger proportion of the recorded flora in comparable to the above-mentioned previous study, their ratio increased from (≈23% to ≈28%). These plant species share their widespread occurrence and often dominance in open habitats such as marshes of El Ballah region in the Isthmus of Suez.

The chorological analysis of the recorded flora indicated that it was a result of a meeting point of several *Phytochoria*. The most important of them were: Mediterranean region, Saharo-Arabian region, Irano-Turanian region and Paleotropical Kingdom. It also revealed that the Mediterranean elements (mono, bi – or pluriregional) constitute the main floristic categories for the recorded species with a total of ≈63% of the recorded flora. The presence of such high ratio of Mediterranean species in the floristic inventory of the recorded flora emphasize the impact of the prevailing Mediterranean climate. This result was consistent with what had been reported in the earlier phytosociological studies on farmland Northeast Delta region (El-Demerdash et al., 1997; Mashaly et al., 2002, 2010; El-Amier et al., 2015a,b; El-Amier and Abd El-Gawad, 2017). However, although the Mediterranean element was well represented in all the identified VSG (A-D) with convergent ratios, the result of ANOVA indicated that the variable was statistically nonsignificant. Moreover, the measurement of the sample variance of the parameter showed a medium spread-out of the data points ($S^2 = 0.097$). This could be attributed mainly to the change of the prevailing climatic conditions of the area. Upon viewing the metrological data obtained from the Egyptian Meteorological Authority (EMA) it is obvious that the climate of the area characterized by low annual rainfall and it lacked the heavy rainy winters that were reported in case of the coastal farmland of Northwest Delta. Moreover, according to the Köppen-Geiger climate classification system (updated world map by Peel et al., 2007) the climate of Ismailia province classified as hot desert (BWh). In such arid climate there is an excess of evaporation over precipitation. It is easy to understand how climate can vary over very large areas, because of slight changes in temperature or rainfall. However, climates can also vary over very short distances. This local differences in climate are described by the term “microclimate”. Hence, the prevailing climate (relatively drier Mediterranean climate (microclimate)) decreased the impact of Mediterranean climate in comparable with what has been reported in coastal farmland and adjacent territories in northwest delta region (Mahgoub, 2019). The vegetation vulnerability to climate change (microclimate) was remarkable in the results of the present study. In comparison with the previous study a remarkable decrease was observed in the number of recorded winter weeds. They decreased from 299 species to 124 species or from≈ 63% of the recorded flora to ≈51%. Most of these species are annuals Mediterranean species. Their occurrence in ecological niche matched to the presence of their specific environmental conditions which related first with the plentiful of water resources that are mainly available in arid habitats through high ratios of rainfall. Moreover, we can also observe a decrease in the ratio of species which belong to class V (rare constancy weed species). They constituted only about 37% of the recorded flora rather than half (≈52%) in the former study. This increase in plant composition homogeneity was detectable in ANOVA test which indicated that species richness was statistically nonsignificant and in the decline of total species richness γ-diversity, Whittaker. The total number of species recorded decreased from 473 species to 245 species. It should be also pointed out that the number of the recorded Mediterranean species further southwards to the study area toward the Suez Gulf was an express for the gradual cease of the impact of the Mediterranean climate on species distribution and weed community structure. The ratio of Mediterranean species did not exceed 28% of the recorded flora in the phytosociological studies on Wadi Hagul which lies at the Northwestern part of Suez Gulf (Kassas and Zahran, 1962; Mashaly, 1996; Abdelaal, 2016). It is always expected that the climate change will almost certainly lead to changes in the distributions of species (Parmesan, 2006) and changes in species composition may lead to reassessment of effects of control on surrounding, non-target species (Hellmann and Byers, 2008). However, a changing climatic condition does not imply a radically different set of options for agricultural practices, but will likely necessitate changes in the timing or intensity of control mechanisms. For example, weeding or pesticide applications may need to be moved earlier in the spring to account for shorter winters and earlier spring events (Rahel and Bierwagen, 2008).

The impact of urbanization on vegetation structure has been addressed in several ecological studies. Many of these studies related to urban vegetation are dealing with temporal changes in the plant composition (e.g., Florgård, 2000; Godefroid, 2001; DeCandido, 2004; Pyšek et al., 2004), plant distribution along urban–rural gradients (e.g., Godefroid and Koedam, 2003a; Daniel and Lecamp, 2004), fragmentation (e.g., Bastin and Thomas, 1999x; Stenhouse, 2004; Guirado et al., 2006), alien species (e.g., Pyšek, 1998; Godefroid and Koedam, 2003b), effect of urban development on native species (e.g., Vale and Vale, 1976; Luniak, 1994; Kowarik, 1995 and Marzluff, 2001) and biodiversity (e.g., McKinney, 2002; Zerbe et al., 2003; Cornelis and Hermy, 2004; Kühn et al., 2004). The use of "the number of introduced species to the area" as an indirect measure for the degree of human disturbance and urbanization has been highlighted in some phytosociological studies (Mashaly, 1996; Abdelaal, 2016; Mahgoub, 2019). In addition, the urban-gradient studies showed that, for many taxa, for example, plants (Kowarik, 1995), the number of nonnative species increases toward centers of urbanization, while the number of native species decreases. Hence, the number of introduced species to an area (new recorded species in an area or nonnative species to an area) could be described as a bioindicator in response to human impacts on vegetation structure from one area to the other as assessed in the present study. The sample area under study included El Ballah region in the Isthmus of Suez and like many Isthmuses, the Isthmus of Suez of Egypt has a great strategic value. Its value had increased notably after the completion of the construction launched by the Suez Canal Authority (SCA) in August 2014 to expand and widen the Ballah Bypass to speed the canal's transit time and double its capacity for ship passage. The completion of the project in 2015 brought more investments to the region and has increased the urbanization rate in the last few years. One aspect of this increase in urban development was the increase in the rate of land reclamation which increases the probability of the presence of an effective impact of urbanization on vegetation structure. However, urbanization showed a lower impact on vegetation structure in comparable with the previous study and the number of introduced species to the area was 45 species instead of 101 species in the former study. The highest urbanization impact was scored in VSG A sites facing the Suez Canal where the project had launched and the group had scored the highest species richness as well.

This result contrast what was reported in the former study where the group which scored the highest urbanization had scored the least species richness. The urban-to-rural gradient studies indicated that the increasing fragmentation of natural habitat by human disturbances in the direction toward urban centers will tend to reduce species richness (number of species) in that direction (Kowarik, 1995; Blair, 2001; Denys and Schmidt, 1998; Mackin-Rogalska et al., 1988). There are, however, many variables that can affect the rate and consistency of species loss along the gradient and in such desert subjected to land reclamation the native species of the natural vegetation struggle to survive and the weeds trying to compete with them. It addition, species vary in their ability to adapt to the often drastic physical changes along the urban–rural gradient (Gilbert, 1989; Adams, 1994). The ANOVA test indicated that the variable was statistically nonsignificant and the measurement of sample variance (S^2) also indicated that the parameter scored the least spread-out of the data points (=0.009). It may be possible that the increase of urbanization in the future and the increase in land reclamation rate will cause a corresponding increase in the effect of the variable on vegetation structure.

From different environmental factors, soil properties are of prime importance as they directly influence plant growth and distribution (Hoveizeh, 1997). Furthermore, several other researches revealed the effect of soil texture and properties on vegetation structure. Letey (1985); Hamblin and Hamblin (1985) and Passioura (1991); had indicated that soil structure—the spatial arrangement of individual particles, their aggregates, and of pores—plays a multifaceted key role in the factors determining crop and vegetation performance. Zhang et al. (2006); declared that the pattern of assemblages within communities depend on both soil variables (e.g. N, P, K and organic matter) and topographic variables. James et al. (2005); had revealed that topographic gradients in arid conditions usually are coupled with differences in decreasing soil fertility and increasing salinity, pH and concentrations of toxic elements like Na and B. Naz et al. (2010); had discussed the impact of soil salinity as one of the major determinants of community structure under arid environments. Tsoar (1990); had declared that precipitation also percolates to a greater depth on coarse-compared to fine-textured soils. Also, the impact of soil texture on above-ground net primary productivity (ANPP) of plant communities had been discussed by Lane et al. (1998); Sala et al. (1988) and Le HouŽrou (1984). The hypothesis of the inverse-texture effect is based on the assumption that soil texture controls water availability, a primary control on ANPP. However, soil texture may also exert a control on nutrient availability. Generally, fine-textured soils have higher levels of soil organic matter and greater nutrient availability than coarse-textured soils (Parton et al. 1987, 1993; Burke et al. 1989). The results of the current study had showed that the variation of plant species composition was strongly spatially structured by soil type and properties. There was a clear pattern in the distribution of site groups in cluster and multivariate analysis indicating that the floristic variation in the data set was mainly related to environmental differences between reclaimed land and fertile land. This could be recognized through several items. Depending upon their floristic composition, AHC and PCA had separated reclaimed land sites characterized by their high soil content of sand; low water holding capacity and high soil salinity from the more fertile land sites characterized by their high soil content of clay and silt; high water holding capacity and low soil salinity. Moreover, the analyses separated the reclaimed sites of El Ballah region of Isthmus of Suez dominated by fine sand (VSG A) from those of east-delta region dominated by coarse sand (VSG B) and from the remaining sites of east-delta region dominated by clay and silt (VSG C and VSG D). The sites of the first two groups gained the highest positive factor scores on PC1, while most of the sites of the two other groups gained negative factor scores on PC1. However, more than one soil type was identified in each group. The analysis of soil samples indicated that from 2 up to 5 soil types were identified in each sampling site in comparable to a maximum of three soil types in the former study. The discovery of this high variance in soil texture was continued in the identified site groups. The most affected was VSG B. In some farmland belong to this group, the ground level was elevated forming patches of gravelly or gritty sandy soils of deltaic stage of river terraces (sand islands) organized into an arch of high land that appear inside the fields which were dominated by clay or loam soils. Furthermore, the impact of soil type and properties on the diversity of the identified groups (VSG) could be detected through several other items: the detected overlap in the convex hulls between VSG A and VSG B in the PCA correlation biplot; the convergent values of the pairwise beta diversity index (Whittaker's (β) diversity) for VSG B vs VSG A and for VSG B vs VSG C; and the complete separation of the farmlands which belong to the famous archeological site Tanis (Ta5) or San El-Hagar to the far negative end of PC1 during PCA and into a vegetation sociation group (VSG D) during cluster analysis (AHC). The analysis of soil samples of farmlands which belong to this site had indicated that the soil texture characterized by the highest content of clay and silt. These heavy soils with very fine granules, poor drainage and high salinity are not suitable for agriculture. In addition, several farmlands in some localities belonging to the site are threatened with inundation or inundated by Lake Manzala. In such poorly drained water-saturated soils, successful cultivation is heroic. The cultivated crops in most of these farmlands became either neglected by farmers or abandoned. However, the other some have been reclaimed as rice cultivations to the north and the refugees founded the nearby city of Tanis (San al-Hagar el-Qebleyah). These ecological conditions enhanced the growth of certain species rather than others, thus increasing the variability in floristic composition of the group (VSG D). It had scored the highest D value and lowest S, H and E values and the number of recorded weeds in the site during the summer half of the year exceeded those recorded during the winter half contrast to all other sites. ANOVA revealed that the impact of soil type and properties was the most statistically significant environmental variable comparable to other eco factors under study. The measurement of the sample variance for the sites' indicative scores for the parameter indicated a high spread-out for the data points of the variable ($S^2 = 0.193$). This high spread-out for the data in comparison to the result of the previous study (Mahgoub, 2019) is one of the main causes for the difference in the order of importance of this eco factor. The present findings emphasize that soil type is the most impacting factor on species distribution and weed community structure and this coincides with the view of several other phytosociological studies (Pan et al., 1998; Mehrjardi et al., 2009; Pinke et al., 2010; Diouf et al., 2012; Ward et al., 2014; Ahmad et al., 2016; Khan et al., 2018).

The records of the types of the cultivated crops in the 10 sampling sites (districts) monitored indicated a strong correlation between the type of crop cultivated and soil type. However, the number, type and quantity of cultivated crops differ from one site to the other and the cultivation of a certain crop type is a conclusion of what is available from natural resources; as soil type, quantity of farmland suitable for cultivation, plentiful of water, prevailing climatic conditions, ecological amplitude of the crop, human requirements, …etc. But in general, the cultivation of sandy soil crops was preferred in reclaimed land sites of El Ballah region in Isthmus of Suez, while clay and loamy soil crop cultivation was prevalent in the sites of adjoining farmland east of Nile delta. The impact was evident through the results of PCA. The projection of the initial variables in the factor space showed that crop type and crop sustainability were strongly positively correlated with soil type and the acute angles in the correlation circle between the vectors of crop type, crop sustainability, species richness (S) and weed seasonality indicated that they were significantly positively correlated. Fried et al. (2008), concluded that soil pH and soil texture resulted in highly contrasting weed communities on basic clay soils against those on acidic sandy soils and the major variations in species composition between fields were associated with human management factors; (1) the current crop type and (2) the preceding crop type. Furthermore, the heterogeneous field conditions are inherent in most agricultural fields (Cook and Bramley, 1998; Robert, 2002). This heterogeneity can be manifested in soil fertility (Reyniers et al., 2006), hydrological properties (Reyniers et al., 2006) and/or weed communities (Cardina et al., 1997; Rew and Cousens, 2001). Thus, the composition of weed communities is influenced by dramatic variations in crop characteristics and management regimes (Doucet et al., 1999) and weed community assembly is driven by a sequence of field-scale disturbances and stresses that may be interpreted as assembly filters (Booth and Swanton, 2002). Hence, the relatively stronger correlation between soil type with crop type and crop sustainability was one of the main reasons for the increased impact of the two variables in comparable to the former study. The highest number of cultivated crops was recorded in AM6 (VSG B) and the highest value of crop sustainability scored in AQ10 (VSG A). That increase in crop diversification had affected the diversity and floristic composition of the two groups more than the two other ones. They scored high values of S, H and low values of E, D and in the PCA correlation biplot, an overlap in convex hulls between the two groups was detected. Several other results emphasized the impact of the two variables: the difference in number and performance of species associated with weed communities in different crop categories (CW = 180 sp., CS = 133 sp. and CO = 163 sp.); the seasonality of weeds (A = 32 sp., W + Ws = 124 sp. and S + Sw = 89 sp.) and the measurement of the degree of seasonal bias (Sb%) which indicated that ≈30% of the recorded species designated Ws and Sw. They constitute ≈64% of the high-constancy weeds characterized by wider ecological amplitude. Such higher ratio in comparable to what was reported in the former study (≈33%), indicated a higher impact of the two variables, as well. The growth of these weeds (Ws & Sw) often associated to the early cultivations of some winter and summer crops (e.g. clover, tomato, cotton, watermelon, etc.) and mostly they were well represented in them and in orchards, as well. The notes of their phenology (timing of life cycle events) indicated that most of them have more than one seasonal growth cycle during the season of crop cultivation i.e. produce several generations. These and other weeds cause great destruction to crops as they increase the coasts of different cultural practices, decrease the effectiveness of agricultural equipment and excellence of fertile lands, decrease the gemination capability of crops seed due to the phytotoxins or allelochemicals (Algandaby and Salama, 2018). The extent of persistence and resistance of these weeds against weed control plans (weeding, hoeing, ploughing, herbicides, Stale seed bed, farming practices, ….etc.) as the case of other weeds, depend mainly on the genetically inherited characters and the mutations and gene flow which contribute to genetic variability and provide resistant alleles (Mahgoub, 2019). The medium to low scores for sample variance of the indicative scores of sampling sites for crop type and crop sustainability (S2 = 0.09, 0.03) indicated that the floristic composition of most sampling sites was affected and it was clearer at VSG A and VSG B sampling sites, as mentioned earlier. The ANOVA test showed that the two variables also statistically significant.

5. Conclusion

The change of the combined effects of the eco factors from one region to the other has significant adverse impact on ecological range of some species and their spatial distribution, which depends mainly on the higher ecological amplitude of species and wider ecological niche. In comparable to the former study (Mahgoub 2019), a tangible decrease of the total species richness γ-diversity, Whittaker, was observed and we conclude a different order of importance for the impact of the five eco factors. The soil type was the most impacting factor on species distribution and weed community structure followed by: crop type, crop sustainability, the prevailing climate and urbanization, respectively. However, we should keep in our mind that this order of importance of the impact of these environmental factors is realistic for the sample area under study, but it is not a strict rule, as an ecological factor may be the dominant in determining the vegetation structure in a certain region and co-factor in another one depending on the available natural resources and extent of human intervention.

Declarations

Author contribution statement

Alaa Mahgoub: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

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