Article

Fl. Medit. 30: 65-79
https://doi.org/10.7320/FlMedit30.065
Version of Record published online on 1 June 2020

W. M. Amer, N. F. Elshayeb, A. K. Hegazy, M. S. Abbas, A. S. Soliman & M. M. Abdel Wahab

Species diversity and climate an intimate relationship over the last decades in the Mediterranean region: the case study of Sallum Sector, Egypt

Abstract

Amer, W. M., Elshayeb, N. F., Hegazy, A. K., Abbas, M. S., Soliman, A. S. & Abdel Wahab M. M.: Species diversity and climate an intimate relationship over the last decades in the Mediterranean region: the case study of Sallum Sector, Egypt. — Fl. Medit. 30: 65-79. 2020. — ISSN: 1120-4052 printed, 2240-4538 online.

The Mediterranean coastal land is one of the richest phyto-geographic territories of Egypt owing to its relatively high rainfall. Sallum sector is situated in the Libyan-Egyptian border. This study deals with, the vegetation covers in different habitats, floristic composition, species richness, species diversity, and chorotypes in Sallum sector. The current floristic composition was compared to that from the last ten decades, to elucidate: the past-present and the future vegetation trend; the change in floristic composition through these decades; trace the impact of climatic changes represented by temperature and rainfall. And, trace the desert expansion as the spatial distribution of the SaharoSindian chorotype. The combined dataset has demonstrated a poleward species sift, notable differences in their response to shortage in rainfall and increased temperatures, were observed among the recorded chorotypes and the species composition across studied habitat range. The SaharoSindian chorotype showed poleward expansion. The retrieved data including, a decline in the total number of the recorded species, changes in their distribution range, recording the timing erosion and the northward expansion of some indicator species. The decline in mean annual rainfall was inconsistent with positive shift in the mean maximum temperature with 1.5°C. Northward expansion of xerophytes and loss of species diversity through the studied successive decades. Such study provides a case study for the effect of climatic changes in arid land, to support the climatic scenarios. Finally, urgent need of conservation effort and mitigation measures to control the genetic erosion in such arid coastal sector.

Key words: Mediterranean vegetation, climatic change, distribution shift, drought tolerant species, arid land.

Introduction

The Mediterranean coastal land is one of the richest phytogeographical territories in Egypt. It extends for 970 km from Sallum on the Egyptian-Libyan border in the west to Rafah on the Egyptian-Palestine border in the east with an average coastal belt 15-20 km, in north-south direction El-Hadidi (1980). Sallum sector, representing the most western limit of the Mediterranean coastal land of Egypt, belongs to the Mareotis sector and is characterized by an attenuated desert climate. This sector extends from Sallum in the west to Ras El Hikma in the east Salama & al. (2005).

The general feature of the Sallum sector is the presence of limestone plateau crossed by shallow wadis running South to North which ends with limestone ridge close to the seashore of about 200 m a.s.l. (El-Hadidi 2000).

The previous records of the floristic elements in this sector comprised both Mediterranean and Saharo-Arabian types owing to its phytogeographic position, which lies within the Mediterranean/Saharo-Arabian regional transition zone White (1993).

Nevertheless, floristic composition and phytosociology of this sector were dealt with several earlier studies, claiming that this sector remains one of the floristically less known territories in Egypt (Abdelaal & al. 2019). Hitherto, previous studies in the past few decades did not cover the environmental impacts on natural flora including both climatic and anthropogenic activities (Osman & El Garf 2015).

Climate is the biggest overall factor determining plant distribution and the main world types of climate are related to vegetation features. Climatic factors control not only the growth of plants but also the development, distribution, and densities of the vegetation of the earth. Climate is the biggest overall factor determining plant distribution and the main world types of climate are related to vegetation features (Zahran 1989). The climate change scenarios suggest that there is considerable uncertainty about possible future ecological impact, some scenarios produce opposite signs for ecological responses (Bachelet & al. 2001; Hegazy & al. 2008). Climatic changes are also expected to alter the distributions of most types of vegetation **(**Cramer & al. 2001; Scholtze & al. 2006). Besides, Parmesan (2007) claimed that only long-term field observations can reveal complex interdependencies between species, an essential component in estimating future responses to global warming. Therefore, this study was carried out to analyze the floristic composition, species richness, evenness, and species diversity during the last ten decades (1925-2018), in Sallum sector, to provide a past-present-and the expected future vegetation trend. Floristic and climatic data were collected from previous studies, herbarium records, and field inspection. Aiming to elaborate the following: 1- vegetation change through the last ten decades in terms of species types and chorology. 2- The impact of climatic changes as represented by temperature and rainfall. And, 3-The northward desert expansion monitored as the spatial distribution of xerophytic species.

Material and Methods

Study area: The study area in Sallum Sector is bordered from the east by Ras El-Hekma in the east at 27°51’E and 31°15’N that extends to 10 km westwards to Sallum city at 25° 9’25.32”E and 31°34’38.81”N. The sector extends from the seashore and runs 15 km southward to the fringes of the Diffa plateau (Fig. 1). Sallum sector was selected due to its lack of urbanization and on the availability of huge literature data, and the yearly excursion through educational program in Botany and Microbiology Department.

Recent vegetation analysis: the field observation and literature data indicating that the vegetation and soil showed considerable variability in this sector. Accordingly, six sites were select-

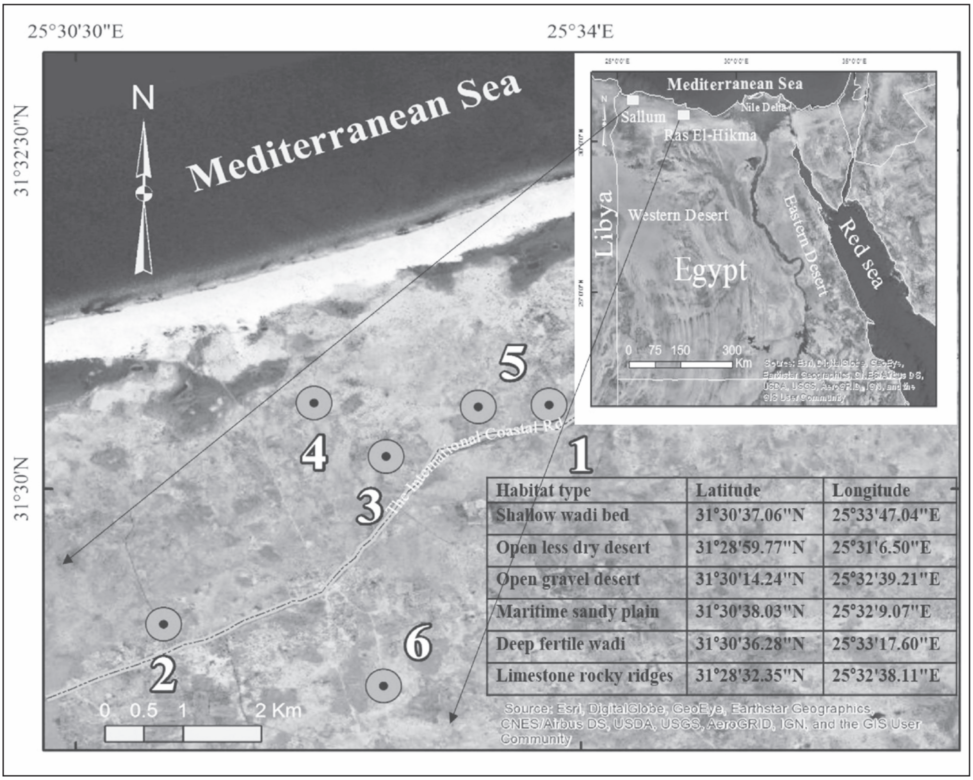

Fig. 1. The representative vegetation sampling sites in the studied Sallum Sector (Egypt).

ed (each represented by squares of 20 × 20 m), to cover the vegetation of the different habitat types namely: shallow wadi, open desert with moist sand-sheet, open-gravel desert, calcareous-maritime sandy plain, deep wadi and the limestone rocky ridge (Fig. 1).

The species in each square were identified, counted and representative specimens were deposited in the Cairo University Herbarium (CAI). The sites were localized using a GPS model BHC NAVA 300 (positioned in Fig. 1 as the square centre point). Identification of taxa was based on voucher herbarium specimens and the reference books Täckholm (1974), Cope & Hosni (1991), Boulos (1999, 2000, 2002, 2009), while Wickens (1978) and Zohary (1973) were followed for species chorology.

The studied ecological parameters (species density, relative density, frequency, relative frequency, cover, relative cover and importance value (IV), were calculated, based on Phillips (1959). The number of individuals/species in each square (20 × 20 m), were counted in the field. While, the ecological parameters were calculated, based on (Hegazy & al. 1998). Species density = (number of individuals/square area). Relative density= (density for a species)/ (total density for all species) ×100. Frequency = (number of sampled quadrates in which species occurs)/ (total number of quadrates sampled). Relative frequency = (frequency value for a species)/ (total of frequency values for all species) ×100, Cover

= (total of intercept lengths for a species)/ (total transect length) ×100. Relative cover = (total of intercept lengths for a species)/ (total of intercept lengths for all species) ×100 and Importance Value of a species x = Relative density of the species x + relative cover of the species x + relative frequency of the species x.

Historical floristic composition: The historical data about previous species composition was compiled from the previous studies: El-Hadidi & Ayyad (1975), Yehia (1984 &1992), Shaltout (1985), El-Hadidi & al. (1986), El-kady & Sadek (1992), Kamal & El-kady (1993), Ayyad & Fakhry (1996), Shaltout & El-Kady (1999), El Garf (2003), Salama & al. (2003 & 2005), Osman & al. (2009), Youssef & al. (2014), Osman & El Garf (2015) and Abdelaal & al. (2019). In addition to the data obtained from herbarium specimens deposited in Cairo University Herbarium (CAI). Where, the collection site, was cited on the specimen label, each species site was changes to co-ordinates using Google map then these co-ordinates added to the recent map, for floristic comparison.

Chorological analysis: Chorology was the term given by phyto-geographer to divide the globe into areas with more or less well defined floras. The species traced in this work were related to its phyto-geographic regions according to White & Léonard (1991). The species consider mono-regional when distributed geographically in one region (e.g. Mediterranean region), and bi-regional if present in two regions (e.g. Mediterranean and SaharoSindian), more than two regions is pleuri-regionals.

Climatic data: Climatic data are based on the climatic data retrieved from the "National Meteorological Authority in Egypt" of Sallum Plateau station (No. 305), latitude 31º 57' longitude 25º 13' and elevation 6 m), and covers the last nine decades (92 years) from 1925 to 2017. The mean values of temperature and rainfall as shown in Figure (1), are shown for the periods: 1925-1950, 1946-1975, 1976-2000 and 2001-2017. The fundamental climate is the arid Mediterranean with mild winters, where January is the coldest month with mean minimum temperature ranges from 14.8 ºC during the period from 1925 to 1950, to 18.5 ºC (1976-2000). It was 17.3 ºC during the last 17 years (2001-2017). August is the hottest month with a mean maximum temperature of 30.1 ºC (1925-1950) that increased to 31.1 ºC (1976-2000), and beyond this, the temperature was 31.6 ºC during the last 17 years (2001-2017).

The distribution of the mean annual rainfall (Fig.2), shows a sharp decrease from about 241.2 mm/year during the period 1925-1950 to 105.0 mm/year in 1946-1975 and 98.9 mm/year in 1976-2000. During the last period 2001-2017, rainfall was significantly lower, it reached 53.8 mm/year. Winter is the main rainy season, with a maximum amount of rainfall during the four months November to February. The average maximum monthly rainfall, moved from November in 1925-1950, where rainfall value reached 51.09 mm, and decreased to 23.9 mm in 1946-1976, to January in 1976-2000, where 29.4 mm was the maximum amount recorded in December (2001-2017), with lower values reached 15.7 mm.

Results

Vegetation

The vegetation in this sector during 2018, as represented in this study covered the six habitats.

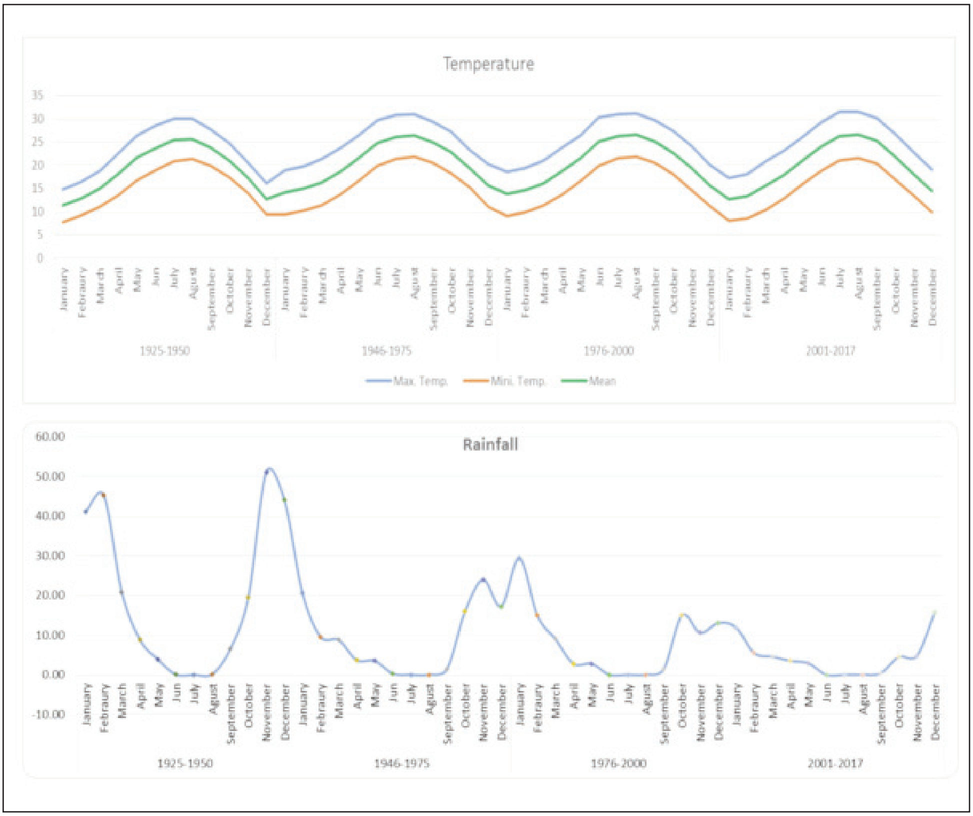

Fig. 2. Indicator climatic data of Sallum Sector as mean values of the studied decades (based on National Meteorological Authority in Egypt).

Shallow wadi bed: This habitat type, characterized by fine sand sheet, and total vegetation cover reached 23%. Table (1) shows that the dominant species based on the importance value (IV) are the annual legume species namely: *Astragalus peregrinus* Vahl (IV 25.6), followed by *A. annularis* Forssk. (IV 23.9) and co-dominated with the Mediterranean perennial species like *Asparagus stipularis* Forssk. (IV 14.0), *Asphodelus aestivus* Brot. (IV 12.6), *Lotus polyphyllos* E. D. Clarke (IV 13.0) and *L. creticus* L. (IV 10.12). While, *Deverra tortuosa* (Desf.) DC. of the SaharoSindian species attained an IV 19.2.

Open less dry non-saline desert: This habitat type retains total plant cover reached 17%. The vegetation dominated by the perennial xeric species: *Haloxylon salicornicum* (Moq.) Bunge ex Boiss. (IV 38.7), *Helianthemum lippii* (L.) Dum. Cours. (IV 33.7) and co-dominated by *Deverra tortuosa* (IV 23.8) and *Gymnocarpos decandrus* Frossk. (IV 19.7). The annual *Salsola kali* L. (IV 10.5) belongs to the Paleotropic species (Table 1).

Open gravel desert: This habitat showed a total plant cover of 22% (Table 1), dominated by perennial Mediterranean-SaharoSindian chorotype: *Thymelaea hirsuta* (L.) Endl. (IV 34.5), *Gymnocarpos decandrus* (IV 17.0) and *Marrubium alysson* L. (IV 11.7). The

Table 1. Vegetation pattern in Sallum sector during 2018, represented by squares "S1-S6" with its ecological parameters, species arranged in each square based on its importance value (IV) and Cover percentage (C%).

Species	**Life duration**	**Floristic categories**	**C%**	**IV**
S 1: Shallow wadi bed with total vegetation cover 23%				
Astragalus peregrinus Vahl	Annual	SA-SI	5	25.65
Astragalus annularis Forssk.	Annual	MED + SA-SI	5	23.92
Deverra tortuosa (Desf.) DC.	Perennial	SA-SI	3	19.28
Asparagus stipularis Forssk.	Perennial	MED	2	14.07
Hyoscyamus muticus L.	Perennial	MED + IR-TR	2	13.05
Lotus polyphyllos E. D. Clarke	Perennial	MED	1	13.003
Asphodelus aestivus Brot.	Perennial	MED	2	12.61
Lotus creticus L.	Perennial	MED	1	10.13
Marrubium alysson L.	Perennial	MED + SA-SI	1	9.28
Brassica nigra (L.) Koch	Annual	MED + ER-SR	1	8.68
S 2: Open less dry non-saline desert plain with total vegetation cover 17%				
Haloxylon salicornicum (Moq.) Bunge ex Boiss.	Perennial	SA-SI + IR-TR + S-Z	6	38.78
Helianthemum lippii (L.) Dum. Cours.	Perennial	SA-SI + S-Z	5	33.18
Deverra tortuosa (Desf.) DC.	Perennial	SA-SI	3	23.88
Gymnocarpos decandrus Frossk.	Perennial	MED + SA-SI	2	19.71
Salsola kali L.	Annual	PAL	1	10.52
S 3: Gravel desert with total vegetation cover 22%				
Thymelaea hirsuta (L.) Endl.	Perennial	MED + SA-SI	6	34.50
Zygophyllum album L. f.	Perennial	MED + SA-SI	4	21.52
Lycium europaeum L.	Perennial	MED	3	19.60
Gymnocarpos decandrus Frossk.	Perennial	MED + SA-SI	2	17.04
Marrubium alysson L.	Perennial	MED + SA-SI	1.5	11.75
Echinops spinosus L.	Perennial	MED	0.8	11.61
Helianthemum lippii (L.) Dum. Cours.	Perennial	SA-SI + S-Z	1.6	11.04
Peganum harmala L.	Perennial	MED + IR-TR + SA-SI	0.6	7.50
Herniaria hemistemon J. Gay	Perennial	MED	0.3	7.42
Astragalus peregrinus Vahl	Annual	SA-SI	0.5	6.19
Asparagus stipularis Forssk.	Perennial	MED	0.1	5.83
Farsetia aegyptia Turra	Perennial	SA-SI + S-Z	0.1	5.40
Haloxylon salicornicum (Moq.) Bunge ex Boiss.	Perennial	SA-SI + IR-TR + S-Z	0.4	5.301
Zilla spinosa (L.) Prantl	Perennial	SA-SI	0.3	4.85
Anabasis articulata (Forssk.) Moq.	Perennial	SA-SI	0.2	3.52
Urginea maritima L.	Perennial	MED+ER-SR	0.5	3.43
Neurada procumbens L.	Annual	SA-SI	0.1	3.06
S 4: Maritime saline sand dunes with total vegetation cover 13%				

Table 1. continued.

Carduncellus mareoticus (Delile) Hanelt	Perennial	MED	5	43.96
Lotus creticus L.	Perennial	MED	2	21.16
Asparagus stipularis var. *tenuispinus* Holmboe	Perennial	MED	2	20.76
Pancratium maritimum L.	Perennial	MED	2	17.12
Lotus polyphyllos E. D. Clarke	Perennial	MED	1	16.34
Ononis vaginalis Vahl	Perennial	SA-SI + IR-TR	1	9.86
S 5: Deep wadi with total vegetation cover 19%				
Atractylis carduus (Forssk.) C. Chr.	Perennial	MED + SA-SI	5	32.24
Astragalus mareoticus Delile	Annual	MED	5	29.64
Hippocrepis cyclocarpa Murb.	Annual	MED	4	24.38
Thymelaea hirsuta (L.) Endl.	Perennial	MED + SA-SI	3	23.01
Marrubium alysson L.	Perennial	MED + SA-SI	1	10.19
Citrullus colocynthis (L.) Schrad.	Perennial	SA-SI	1	7.73
S 6: Calcareous rocky ridge with total vegetation cover 18%				
Deverra tortuosa (Desf.) DC.	Perennial	SA-SI	6	39.57
Herniaria hemistemon J. Gay	Perennial	MED	5	33.83
Thymelaea hirsuta (L.) Endl.	Perennial	MED + SA-SI	3	23.89
Gymnocarpos decandrus Frossk.	Perennial	MED + SA-SI	2	19.05
Farsetia aegyptia Turra	Perennial	SA-SI + S-Z	1	10.50
Salsola kali L.	Annual	PAL	1	10.20

mono-regional Mediterranean elements are represented by the four species: *Lycium europaeum* L. (IV 19.5), *Echinops spinosus* L. (IV 11.6), *Herniaria hemistemon* J. Gay (IV 7.4), and *Asparagus stipularis* (IV 5.8). The mono-regional xeric (SaharoSindian chorotype) include *Zygophyllum album* L. f. (IV 21.5), *Astragalus peregrinus* (IV 6.1), *Neurada procumbens* L. (IV 3.0), *Zilla spinosa* (L.) Prantl (IV 4.8) and *Anabasis articulata* (Forssk.) Moq. (IV 3.5).

Maritime sand dunes: This maritime sand dune is a saline habitat type showed the lowest vegetation cover (13%; Table 1) among the studied habitats. Dominant by perennial psamophytes representing the Mediterranean chorotype. The dominant were: *Carduncellus mareoticus* (Delile) Hanelt (IV 43.9), *Lotus creticus* (IV 21.1), *Asparagus stipularis* (IV 20.9), *Pancratium maritimum* L. (IV 17.1) and *Lotus polyphyllos* (IV 16.3). The only traced bi-regional element in this site was the calcareous sand dune indicator *Ononis vaginalis* Vahl (IV 9.8), belongs to the IranoTuranian-SaharoSindian chorotype.

Deep wadi: this site represents the deep wadi habitat type, with total vegetation cover reached 19% (Table 1). Where the annuals were co-dominant with perennials. The dominant chorotype was the Mediterranean SaharoSindian elements, represented by the three perennials: *Atractylis carduus* (Forssk.) C. Chr. (IV 32.2), *Thymelaea hirsuta* (IV 23.0) and

Marrubium alysson (IV 10.1), and two annual species (*Astragalus mareoticus* Delile IV 29.6 and *Hippocrepis cyclocarpa* Murb. IV 24.3), of Mediterranean chorotype.

Calcareous rocky ridge: this site represents the calcareous limestone rocky ridges habitat type (not exceeding 20 m a.s.l.) with total vegetation cover reached 18% with characteristic xeric perennials (Table 1). The dominant species were SaharoSindian element *Deverra tortuosa* (Desf.) DC. (IV 39.5), and the Mediterranean *Herniaria hemistemon* J. Gay (IV 33.8). The bi-regionals Mediterranean-SaharoSindian chorotype was represented by *Thymelaea hirsuta* (L.) Endl. (IV 23.8), *Gymnocarpos decandrus* Forssk. (IV 19.0) and the common xeric species *Farsetia aegyptia* Turra (IV 10.4).

Taxonomic grouping

The species identified from this sector during field study in 2018 were 198 belonging to 45 families of *Angiospermae* and *Ephedraceae* (*Gymnospermae*), represented by two species. Five families represented 60.6% out of the total recorded species namely: *Asteraceae* (40 species), *Leguminosae* (27), *Poaceae* (25), *Chenopodiaceae* (18), and *Brassicaceae* (10). The other 40 families, were represented by low species richness not exceeding 6, such as *Labiatae* (5 species) and *Boraginaceae* (6 species), while18 families were represented by a single species.

The vegetation in Sallum sector during 2018, is of simple form comprised 41.9% annuals and 58.1% perennials. The annual species were represented in *Asteraceae* (23 species), *Fabaceae* (19 species), *Poaceae* (10) and *Brassicaceae* (8). The highest number of perennials were recorded in *Chenopodiaceae* (15 species).

Chorological analysis

The chorology of the identified species in Sallum sector during 2018, is shown in Table (2). The typical Mediterranean species represent 21.2% (42 species) of the total recorded species that included:Among the characteristic Mediterranean species are: *Arisarum vulgare* Targ. Tozz., *Caralluma europaea* (Guss.) N. E. Br., *Hyoseris radiata* L., *Lobularia libyca* (Viv.) C. F. W. Meissn, *Elymus fractus* (Viv.) Runem. ex Melderis, *Lotus polyphyllos*, *Lycium europaeum* and *Thymalaea hirsuta.* The total mono-regionals species represented 41.9% (83 species), followed by bi-regionals with 40.9% (81 species), and the pleuri-regionals comprises 17.1% (34 species) of the total chorotypes.

Generally, the Mediterranean chorotype is the dominant type (42 species) followed by SaharoSindian (40 species) and the Mediterranean elements extended to SaharoSindian region (MED + SA-SI) which represented by 41 species. The Mediterranean elements extended to IranoTuranian region (MED + TR-TR) that is represented by 10 species. *Allium aschersonianum* Barbey is the only species recorded from the mono-regional IranoTuranion chorotype.

Vegetation feature in the last ten decades:

This study covers vegetation survey during the period from 1925 to 2018. The climatic data showed the negative shift in rainfall and positive temperature shift (Fig.2). The reflection of these shifts on the species presence and diversity in Sallum Sector will be elucidated as a comparison between the historical and the field surveys during 2018 as follows:

Characteristic species of this study sector, since 1925 to 2018, includes: *Globularia arabica* Jaub. & Spach., *Diplotaxis erucoides* (L.) DC., *Lathyrus marmoratus* Boiss. & Blanche, *Scorzonera undulata* Vahl, *Noaea mucronata* (Forssk.) Asch. & Schweinf., *Lycium europaeum*, *Sporobolus pungens* (Schreb.) Kunth, *Teucrium polium* (Decne.) Asch. & Schweinf., *Melilotus messanensis* (L.) All., *Polygonum maritimum* L., *Gagea fibrosa* (Desf.) Schult. & Schult. f., *Marrubium alysson* L., *Caralluma europaea* (Guss.) N. E. Br. and *Asphodelus aestivus* Brot.

During the past decades, the five families namely: *Asteraceae, Fabaceae, Poaceae, Brassicaceae* and *Chenopodiaceae* were the common ones as represented with relatively high number of species. The number of species in four of these families decreased in the recent years, while, the *Chenopodiaceae,* that possesses salt tolerant species, showed higher evenness after 2000 among them *Atriplex halimus* L., *Suaeda aegyptiaca* (Hasselq) Zohary, and *Sarcocornia fruticosa* (L.) A. J. Scott

The field observation and the literature survey about the vegetation in Sallum Sector showed an increase in species evenness and diversity of the halophytic and halotolerant species. Among the species recorded in this sector for the first time after 1950, were *Mesembryanthemum crystallinum* L., and *M. forsskalii* Boiss. *M. nodiflorum* L. traced after 2000. Other species, showed northward expansion after 2000 as *Arthrocnemum macrostachyum* (Moric.) K. Koch, *Atriplex halimus* L., *Suaeda pruinosa* Lange, *S. vera* Forssk. (*Chenopodiaceae*) and *Spergularia marina* (L.) Griseb. (*Caryophyllaceae*).

The mean total number of species recorded in the study sector decreased from 226 species (1925-1950) to 198 species (2001-2018). Similar trend was noticed in perennial species decreased from 128 species (56.6%; in 1925-1950) to 115 species (58.0%, in 2001-2018). The, annuals decreased from 43.3% (98 species) to 41.9% (83 species), in the same intervals. Some of the annual species of Mediterranean-SaharoSindian chorotype were not recorded after 1975, such as *Hippocrepis areolata* Desv., *Astragalus annularis* Forssk. and *Medicago littoralis* Loisel.

Chorotypes shifting

The Mediterranean elements

The chorology of the vegetation elements (species) showed a shift from Mediterranean, IranoTuranian, and EuroSiberian to more xeric elements of SaharoSindian chorotype during the studied ten decades. The number of species grouped under Mediterranean chorotype decreased from 70 species (30.6%) in 1925-1950 to 42 species (21.2%) in 2001-2018 (Fig. 3). Among the Mediterranean elements, not recorded after 1950 is the *Prasium majus* L. Other species were not recorded after 1975 including *Daucus syrticus* Murb., *Malabaila suaveolens* Delile ex Coss., *Arisarum vulgare*, *Erucaria hispanica* (L.) Druce, *Alkanna lehmanii* (Tin.) A. DC., *Ajuga iva* (L.) Schreb. and *Hymenocarpus circinnatus* (L.) Savi. Some of the Mediterranean species sustained to 2018, but showed decreased evenness after year 2000, including *Lathyrus marmoratus* Boiss. & Blanche, *Astragalus hamosus* L., *Papaver rhoeas* L. and *Limonium narbonense* Mill. (Fig.3).

Mediterranean-IranoTuranian elements

The element s of this chorotype decreased from 36 species (15.9%; in 1925-1950) to 10 species (5.0%; in 2001-2018). Some of these species not recorded after 1950 such as *Plantago lagopus* L., while, some other species not recorded after 1975 including *Narcissus tazetta* L., *Eryngium campestre* L., *Garhadiolus angulosus* Jaub. & Spach, *Phagnalon rupestre* (L.) DC., *Ranunculus asiaticus* L.*,* and *Lathyrus gorgonei* Parl. var. *lineatus* (Post) C. C. Towns. Alternatively, populations of some species decreased in the number of individuals by time among them: *Teucrium polium* (Decne.) Asch. & Schweinf., *Melilotus messanensis* (L.) All., *Ranunculus rionii* Lagger, and *Chenopodium giganteum* D. Don.

The contradictory observation was noticed for the halophytic species of the Mediterranean-IranoTuranian chorotype, which showed increased occurrence in its northward distribution such as *Cressa cretica* L. and *Spergularia marina* (L.) Griseb. Elements of the Mediterranean-Euro Siberian chorotype, showed decline such as *Echium rubrum* Forssk., not recorded after the year 1950, *Brassica nigra* (L.) Kochnot recorded after the year 2000, while, *Polygonum maritimum* L. occasionally recorded after the year 2000, in lower species evenness. The halophytic *Sarcocornia fruticosa* (L.) A. J. Scott, showed wider northward distribution and an increase in a number of individuals/population after the year 2000 (Fig.3).

SaharoSindian elements

The species belonging to this chorotype reflecting the xeric nature, where the number of species increased from 22 species (9.7%) in 1925-1950 to 40 species (20.2%) in 2001-2018. The common xeric species such as *Deverra tortuosa* DC., *Anthemis melampodina* Delile, *Heliotropium arbainense* Fresen*., Heliotropium digynum* (Frossk.) Asch. were traced after 1950. While, *Zilla spinosa* (L.) Prantl, *Tetraena simplex* (L.) Beier & Thulin and *Fagonia cretica* L. were showed a wider northward distribution after the year 2000 (Fig.3).

Pluri-regional elements

The elements of Mediterranean-IranoTuranian-EuroSiberian chorotype, decreased in the number of individual/population among them *Senecio vulgaris* L. and *Papaver argemone* L., which showed decreased in species evenness after year 1975. Some other species disappeared after 1975 including *Frankenia hirsuta* L., *F. pulverulenta* L.*, Fumaria bracteosa* Pomel, and *Beta vulgaris* L.

Discussion

Sallum sector encompasses simple vegetation type of highly adapted drought-resistant species, analogous data reported by Salama & al. (2005). Floristic composition, indicated the presence of 60.6% of these species grouped under five families, comprising the flora of Mediterranean North African (Quézel 1978; Shaltout & El-Kady 1999). The recorded species reflect the semi-arid features of Sallum sector (Bornkam & Kehl 1985), while the dominance of therophytes indicates the sector aridity (Salama & al. 2005).

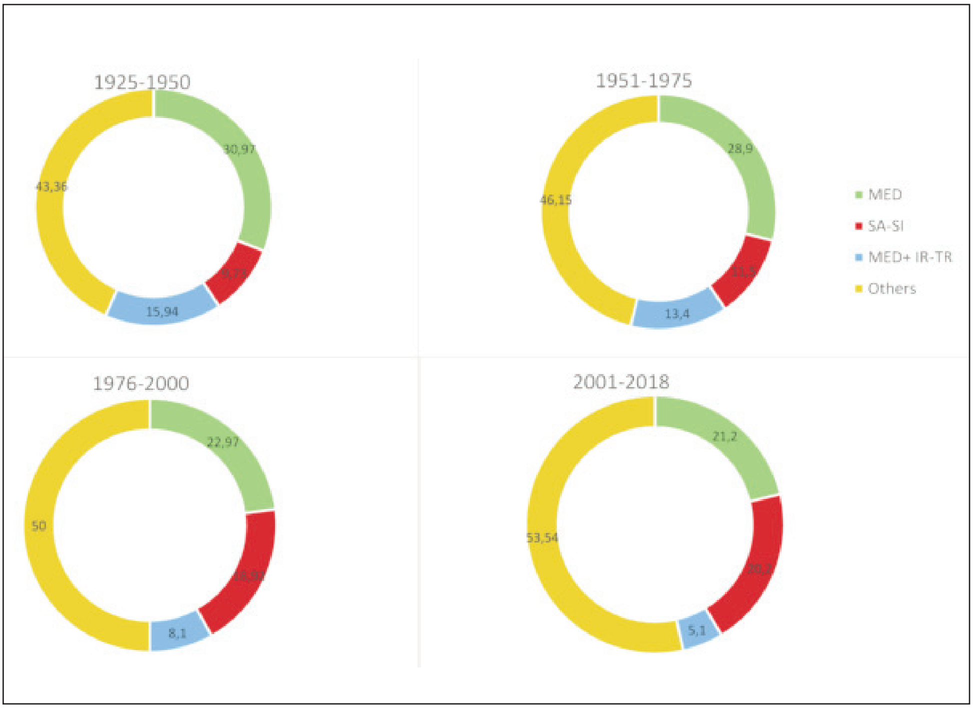

Fig. 3. Shifting in indicator chorotypes during the studied decades in Sallum Sector. The used abbreviations: MED: Mediterranean, SA-SI: SaharoSindian, IR-TR: IranoTuranian, and Others: other chorotypes cited in table 2.

The highest vegetation cover among the studied sites showed up to 23% cover traced in shallow wadi bed (Table 1). In spite of, this site is a part of the Egyptian desert with c. 5% cover (Salama & al. 2005), Zahran & Willis (2009) increased vegetation cover up to 60%. While, flourishing of the annual leguminous (*Astragalus peregrinus* and *A. annularis*) in wadi bed site; enhanced by water and organic matter availability offering suitable micro-habitats; Abdelaal & al. (2019)**.**

On other hand, dry desert habitat (site 2 & site 3); showed lower vegetation cover and dominated by perennial drought tolerant species, as *Haloxylon salicornicum, Helianthemum lippi, Deverra tortuosa* and *Gymnocarpos decanderus* (site 2). While, *Thymelaea hirsuta*, *Zygophyllum album, Lycium europaeum* and *Gymnocarpos decanderus* dominated Site 3. Similar, observation was reported by Zahran & Willis (2009) confirmed the presence of c. 90% perennial xerophytes along with the western Mediterranean coast. The maritime saline sand dunes, prevailing the lowest vegetation cover (13%). This habitat formed of loose pseudo-ooltic sand subjected to sea spray, and dominated by perennial Mediterranean species *Carduncellus mareoticus, Lotus creticus* and *Asparagus stipularis*; indicating the rainfall scarcity (Zahran & Willis 1992).

Table 2. Chorotypes of the plant species collected from Sallum sector. Chorotype abbreviations: MED: Mediterranean, SA-SI: SaharoSindian, ER-SR: EuroSiberian, IR-TR: IranoTuranian, S-Z: SudanoZambezian, COSM: Cosmopolitan, PAI: Palaeotropic, PAN: Pantropic, NEO: Neotropic.

Pytochoria	**Number of species**	**Percentage %**
Mono-regionals		
MED	42	21.2
SA-SI	40	20.2
IR-TR	1	0.5
Sub-total	**83**	**41.92%**
Bi-regionals		
MED + SA-SI	41	20.7
MED + IR-TR	10	5.0
MED + ER-SR	13	6.5
SA-SI + IR-TR	8	4.0
SA-SI + S-Z	8	4.0
IR-TR + S-Z	1	0.5
Sub-total	**81**	**40.91%**
Pluri-regionals		
MED + SA-SI + IR-TR	10	5.0
MED + IR-TR + ER-SR	5	2.5
MED + SA-SI + S-Z	5	2.5
IR-TR + SA-SI + S-Z	3	1.5
MED + SA-SI + ER-SR	2	1.0
MED + IR-TR + SA-SI + ER-SR	1	0.5
COSM	4	2.0
PAL	2	1.0
PAN	1	0.5
NEO	1	0.5
Sub-total	**34**	**17.17%**
Total	**198**	**100%**

The chorotype analysis of the vegetation during 2018 (Table 2), revealed the presence of 41.9% of mono-regional Mediterranean chorotype; reported by Osman & El Garf (2015). While the co-dominance of the SaharoSindian chorotype may be related Sallum position in a Mediterranean Sahara regional transitional zone identified by White & Leonard (1991) and Salama & al. (2005). While, the bi-regional chorotype comprises 40.9% (Table 2); relevant figure was reported by Osman & El Garf (2015).

Among of the Mediterranean species showed notable decreased are *Daucus syrticus* Murb., *Malabaila suaveolens* (Delile) Coss., *Arisarum vulgare* O. Targ. Tozz., *Erucaria hispanica* (L.) Druce, *Alkanna lehmanii* (Tineo) A. DC., *Ajuga iva* (L.) Schreb., and *Limonium narbonense* Mill. Galal & Fawzy (2007) reported 35% decline in the coastal communities. The vegetation composition after the year 1950, showed higher evenness such as *Deverra tortuosa* (Desf.) DC., *Anthemis melampodina* Delile, *Heliotropium arbainense* Fresen and *H. digynum* (Forssk.) C. Chr., others as *Zilla spinosa* (L.) Prantl, *Tetraena simplex* (L.) Beier & Thulin and *Fagonia cretica* L. showed more evenness after the year 2000 (more are outlined in the Electronic Supplementary File 1). The monitored decline in species richness, is inconsistent with Ciccarelli & al., (2012), Ciccarelli (2014) and Abdelaal & al. (2019). Kelly & Goulden (2008) reported that drought-induced 46% vegetation decline, from 1977 to 2007in South California.

Thymelaea hirsuta (L.) Endl. is among the interesting Mediterranean perennial species recorded in all the study sites, with increased species evenness northward and westward. This species restricted to 15-20 km from the seashore to southward (Shaltout & El-Kady 1999). Four decades ago Zahran & Boulos (1973), expanded the range of this species to 75km (from the seashore to southward). Globally, Parmesan & Yohe (2003) reported 6.1 km/decade poleward species shift in many species. However, Bachelet & al. (2001), claimed that climate change scenarios suggest that there is considerable uncertainty about possible future ecological impact, some scenarios produce opposite signs for ecological responses.

This study confirming the northward shift in both of Mediterranean and SaharoSindian chorotypes, where the later replaced the first. This pattern showed an intimate relationship between species diversity and climatic aspects. As Figure (2), outlined the sharp decrease in the mean annual rainfall and temperature increased after the year 1950 by 1.5˚C (Fig. 2). The rainfall decline was reported earlier by Zahran & Willis (2009). While, the recorded positive shift temperature (Fig. 2), supported by Grytnes (2003) and the IPCC (2007) mentioned that the global mean land surface has warmed 0.27 ˚C/decade since 1979. Parmesan & Yohe (2003) cleared that the meta-analysis of long-term (48–132 years) datasets carried out by showed that the geographic location of the northern range boundaries for 100% of 44 species– mirrored decadal temperature trends over the 20th century.

References

Abdelaal, M., Ahmed, D., Fois, M., Fenu, G. & Bacchetta, G. 2019: Floristic patterns and ecological drivers of sand dune ecosystem along the Mediterranean coast of Egypt. – Arid Land Res. Manag. **33:** 388-411. https://doi.org/10.1080/15324982.2018.1564147

Ayyad, M. A. & Fakhry, A. M. 1996: Plant biodiversity in the western Mediterranean desert of Egypt. – Verh.-Gesell. Ökol.**25:** 65-76.

Bachelet, D., Neilson, R. P., Lenihan, J. M., & Drapek, R. J. 2001: Climate change effects on vegetation distribution and carbon budget in the United States. – Ecosystems **4(3):** 164-185. https://doi.org/10.1007/s10021-001-0002-7

Bornkamm, R. & Kehl, H. 1985: Pflanzengeographische zonen in der Marmarika (Nordwest-Ägypten). – Flora **176(1-2):** 141-151. https://doi.org/10.1016/s0367-2530(17)30109-3

Boulos, L. 1999: Flora of Egypt, **1.** – Cairo.

— 2000: Flora of Egypt, **2.** – Cairo.

— 2002: Flora of Egypt, **3.** – Cairo.

— 2009: Flora of Egypt. Checklist. –. Cairo.

Ciccarelli, D. 2014: Mediterranean coastal sand dune vegetation: Influence of natural and anthropogenic factors. – Environ. Manag. **54:** 194-204. https://doi.org/10.1007/s00267-014-0290-2

—, Bacaro, G. & Chiarucci, A. 2012: Coastline dune vegetation dynamics: Evidence of no stability. – Folia Geobot. **47:** 263-725. https://doi.org/10.1007/s12224-011-9118-5

Cope, T. A. & Hosni, H. A. 1991: A Key to Egyptian Grasses. – Kew.

Cramer, W., Bondeau, A., Woodward, F. I., Prentice, I. C., Betts, R. A., Brovkin, V., Cox, P. M., Fisher, V., Foley, J. A., Friend, A. D., Kucharik, Lomas, M. R., Ramankutty, N., Sitch, S., Smith, B., White, A. & Young-Molling, C. 2001: Global response of terrestrial ecosystem structure and function to CO2 and climate change: results from six dynamic global vegetation models. – Glob. Chang. Biol. **7:** 357-373 https://doi.org/10.1046/j.1365-2486.2001.00383.x

El Garf, I. A. 2003: Studies on the shallow wadies of the Mareotis sector of the Mediterranean coastal land of Egypt. 1. Floristic features of Wadi Halazeen. – Bull. Fac. Sci., Assuit Univ. **32(I-D):** 61-71.
El-Hadidi, M. N. 1980: An outline of the planned flora of Egypt, in El-Hadidi, M. N. (ed.) Flora of Egypt. – Taeckholmia, Add. Ser., **1:** 1-12. https://doi.org/10.21608/taec.1999.12641
— 2000: Flora Aegyptiaca, **1(1-2).** – Cairo.
— & Ayyad, M. A. 1975: Floristic and ecological features of Wadi Habis (Egypt). – Pp. 247-258 in Péchoux, P.-Y. (ed.), La Flore du Bassin Mediterranéen: Essai de Systématique Synthetique Colloques Internationaux du C.N.R.S., **235.** – Paris
—, El-Ghani, M. A., Springuel, I. & Hoffman, M. A. 1986: Wild barley *Hordeum spontaneum* L. in Egypt. – Biol. Conserv. **37(4):** 291-300. https://doi.org/10.1016/0006-3207(86)90074-1
El-Kady, H. F. & Sadek, L. 1992: On the phytosociology of wadi Um Ashtan in the western desert of Egypt. – Feddes Repert. **103:** 269-277. https://doi.org/10.1002/fedr.19921030313
Galal, T. M. & Fawzy, M. 2007: Sand Dune Vegetation in the Coast of Nile Delta, Egypt. – Global J. Environ. Res. **2:** 74-85.
Grytnes, J. A. 2003: Species richness patterns of vascular plants along seven altitudinal transects in Norway. – Ecography **26:** 291-300. https://doi.org/10.1034/j.1600-0587.2003.03358.x
Hegazy, A. K.; El-Demerdash, M. A. & Hosni, H. A. 1998: Vegetation, species diversity and floristic relations along an altitudinal gradient in South-West Saudi Arabia. – J. Arid Environ. **38:** 3-13. https://doi.org/10.1006/jare.1997.0311
–, Hammouda, O., Lovett-Doust, J. & Gomaa, N. H. 2008: Population dynamics of *Moringa peregrina* along altitudinal gradient in the northwestern sector of the Red Sea. – J. Arid Environ. **72(9):** 1537-1551. https://doi.org/10.1016/j.jaridenv.2008.03.001
IPCC, 2007: Summary for Policymakers. – Pp. 93-129 in: Metz, B., Davidson, O. R. Bosch, P. R. Dave, R. & Meyer, L. A. (eds), Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change – Cambridge and New York.
Kamal, S. & El-Kady, H. F. 1993: Vegetation analysis of some wadis in the Egyptian Mediterranean desert. – Feddes Repert. **104:** 537-545. https://doi.org/10.1002/fedr.19931040718
Kelly, A. E. & Goulden, M. L. 2008: Rapid shifts in plant distribution with recent climate change. – PNAS. **105 (33):** 11823-11826. https://doi.org/10.1073/pnas.0802891105
Osman, A. K., El Garf, I. A. & Nasr H. 2009: Studies on the shallow wadies of the Mareotis sector of the Mediterranean coastal land of Egypt. 2- Floristic features of Wadi Abu Lamguor. – Pp. 1-16 in: Proceedings of 7th International Conference of the Egyptian Society of Biotechnology and Environmental sciences in collaboration with Istanbul Technical University & the Egyptian cultural centercentre. 7-9 August 2009. – Istanbul.
— & —2015: Studies on the shallow wadies of the Mareotis sector of the Mediterranean coastal land of Egypt: Floristic features of Wadi Hashem. – Fl. Medit. **25:** 57-71. https://doi.org/10.7320/FlMedit25.057
Parmesan, C. 2007: Influences of species, latitudes and methodologies on estimates of phenological response to global warming. – Global Change Biol. **13(9):** 1860-1872. https://doi.org/10.1111/j.1365-2486.2007.01404.x
— & Yohe, G. 2003: A globally coherent fingerprint of climate change impacts across natural systems. – Nature **421:** 37-42. https://doi.org/10.1038/nature01286
Phillips, E. 1959: Methods of Vegetation Study. – New York.
Quézel, P. 1978: Analysis of the flora of Mediterranean and Saharan Africa. – Ann. Missouri Bot. Gard. **65:** 479-534. https://doi.org/10.2307/2398860

Salama, M. F., Abd El-Ghani, M. M., El-Naggar, S. M. & Baayo, K. A. 2003: Floristic composition and chorological analysis of the Sallum area, west Mediterranean, Egypt. – J. Union Arab. Biolog. Cairo **13(B):** 27-47.
—, —, — & — 2005: Vegetation structure and environmental gradients in the Sallum area, Western Mediterranean Coast, Egypt. – Ecol. Mediterr. **31(1):** 1-13.
Scholze, M., Knorr, W., Arnell, N. W. & Prentice, I. C. 2006: A climate-change risk analysis for world ecosystems. – Proc. Natl. Acad. Sci. USA **103:** 13116-13120. https://doi.org/10.1073/pnas.0601816103
Shaltout, K. H. 1985: On the diversity of the vegetation in the western Mediterranean coastal region of Egypt. – Pp. 16-19 in: 4° Egyptian Conference of Botany, Ismaileyah, 16-19 Apr 1985. – Ismaileyah.
— & El-Kady, H. 1999: Species diversity of the ruderal habitats in the Nile Delta. – Taeckholmia **19:** 203-225. https://doi.org/10.21608/taec.1999.12647
Täckholm, V. 1974: Student's Flora of Egypt. 2nd ed. – Cairo, Beirut.
White, F. 1993: Long distance dispersal and the origins of the afromontane flora. – Sonderbericht Nat. Ver Hamburg **7:** 87-116.
— & Léonard, J. 1991: Phytogeographical links between Africa and Southwest Asia. – Flora et VegetatioMundi **9:** 229-246.
Wickens, G. E. 1978: The flora of Jebel Marra (Sudan Republic) and its geographical affinities. – Kew.
Yehia, S. 1984: Ecological studies on the colonization of plants on fresh blown sands in the Coastal Mediterranean sand dunes ecosystems West of Alexandria, Egypt. – M.Sc. Thesis. Cairo University, Egypt.
— 1992: Studies on the germination of some palatable leguminous plants in The Coastal Desert of North Africa for reseeding deteriorated grazing land. – Ph.D. Thesis. Cairo University, Egypt.
Youssef, A. M., Morsy, A. A., Mosallam, H. A. & Hashim, A. M. 2014: Vegetation and soil relationships in some Wadies from the north-central part of Sinai Peninsula, Egypt. – Minia Sci. Bull. **25(1):** 1-28.
Zahran, M. A. & Boulos, S. T. 1973: Potentialities of the fiber plants of the Egyptian flora in national economy. II *Thymelaea hirsuta*. – Bull. Fac. Sci. Mansoura Univ. **1:** 77-87.
— & Willis, A. J. 1992: The vegetation of Egypt. – London.
— & — 2009: The vegetation of Egypt (2nd ed.). – Dordrecht.
Zohary, M. 1973: Geobotanical foundations of the Middle East, **1-2.** – Stuttgart.

Addresses of the authors:
Wafaa M. Amer[1*], Nehad F. Elshayeb[2], Ahmed K. Hegazy[1], Mohamed S. Abbas[2], Amira Sh. Soliman[2] & Magdi M. Abdel Wahab[3],
[1]Botany and Microbiology Dept., Faculty of Science Cairo University, Egypt. E-mail: wamer@sci.cu.edu.eg, akhegazy2202@hotmail.com
[2]Natural Resources Department, Faculty of African Postgraduate studies, Cairo University, Egypt. E-mail: nehadelshayb@cu.edu.eg, msaelsarawy@yahoo.com & sitamira2000@yahoo.com.
[3]Climate, Astronomy and Space Sciences Dept., Faculty of Science Cairo University, Egypt. E-mail: Magdy@Sci.cu.edu.eg
* Corresponding author