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Environmental Factors that Influence the Spatial Distribution of Extreme Halophytes on Egypt's Northwestern Mediterranean Coast

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ABSTRACT

Climate change exerts a significant impact on coastal ecosystems, primarily through the rising sea levels, which pose a global threat to salt marshes, essential habitats for valuable halophytic plant species. Concurrently, unchecked human activities also pose a considerable risk to halophytes. Consequently, comprehending the factors that shape plant community diversity and distribution becomes pivotal for biodiversity conservation and the restoration of degraded vegetation. To address this, we selected 54 stands across the northwestern Mediterranean coast of Egypt, encompassing a salinity gradient, mirroring the global distribution of temperate salt marshes. Soil samples were collected across these 54 locations for comprehensive soil parameter assessments. The studied region was inhabited by 165 species, spread throughout 117 genera and 36 families. The most abundant families in terms of species are the Asteraceae, Poaceae, Fabaceae, and Amaranthaceae. Therophytes were the most represented life form. A multivariate analysis was applied to identify the environmental elements that might have an impact on species distribution. After using TWINSPAN and DCA as classification and ordination approaches, four vegetation groups emerged. Salinity condition influences the distribution of halophytic species, community structure, and wild community diversity. With the escalating human intervention in agricultural operations and the intensification of land usage, the seaward area has been completely degraded except for small patches and there is no possibility of rehabilitation. As a result, steps should be taken to conserve salt marsh habitats against unrestricted land use.

***Keywords*:** Extreme Halophytes, coastal ecosystems, environmental factors, Soil salinity.

INTRODUCTION

According to projections, the global population will increase to 9.1 billion individuals by the year 2050 (FAO, 2011). As a result, to keep up with this rise, global food production would need to be increased by up to 70% by that time (Tester & Langridge, 2010). The aforementioned objective will require a yearly average augmentation in grain output throughout the course of the subsequent four decades, resulting in an additional 38% escalation beyond the established patterns of production. The urgency of attaining this objective is compounded by the diminishing accessibility of cultivable land resulting from urbanization and soil deterioration, hence rendering its accomplishment progressively more complex. (Khan, 2003; Mukhopadhyay *et al.*, 2021; Khamidov *et al.*, 2022). In addition, Soil salinization is becoming more prevalent as a significant concern worldwide, particularly in arid and semi-arid areas. This issue can be attributed to a multitude of sources, both natural and anthropogenic in nature. The severity of such issues is further amplified by the phenomenon of global climate changes, which is projected to escalate both the frequency and intensity of drought-induced stress, storms, and rising sea levels (Hassani *et al.*, 2021; Mukhopadhyay *et al.*, 2021).

As a result, there is a growing demand for salt-tolerant species and alternative crops that may be used as food, animal feed, energy sources, therapeutic compounds, and landscaping decoration plants (Kirwan *et al.*, 2010; Fagherazzi *et al.*, 2019).

Many halophytes may be good prospects for commercialization as cash crops. The salt marshes, seashores, coastal regions, and briny deserts of the entire globe are all natural habitats for halophytes (Obón *et al.*, 2020). The major hallmark of all halophytes is their ability to amass significant levels of NaCl within their cellular structures (Hasanuzzaman *et al.*, 2014) . Obviously, these plants can tolerate and survive under saline conditions that exceed those typically found in seawater (Yensen, 2006). Furthermore, halophytes possess the potential to serve as a viable biological approach for the restoration of saline lands. This is achieved by their ability to extract substantial quantities of salt from the soil and effectively reduce the water table. In traditional medicine, various halophytic species have an essential role in treating ailments all over the world, including: *Atriplex halimus* (Kabbash, 2016), and *Suaeda vermiculata* (Bidak *et al.*, 2015). Unfortunately, climate change is having a severe impact on coastal ecosystems due to rising sea levels, which might potentially result in the inundation of salt marshes worldwide, which are the habitat for those precious plant species. In addition, unmanaged human activities are endangering halophytes which are a promising natural resource. Accordingly, understanding the factors influencing plant community diversity and distribution will provide direction for biodiversity conservation and restoration of degraded vegetation. This study endeavors to enhance our understanding of intricate saline habitats and aims to provide a comprehensive overview of the intricate interplay between halophytes and their associated environmental factors. Additionally, it seeks to meticulously describe and analyze the floristic composition and vegetation types within these

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environments, thereby painting a more complete picture of these complex ecosystems.

MATERIALS AND METHODS

Region of the study

The coastal saline areas are prominent in the Mediterranean coastal zone, which play a crucial role in the region's ecosystem. Especially, The Western Mediterranean coastal belt. Accordingly, the study area was carefully selected by tracking salt-affected habitat in different regions of the Western Mediterranean Coastal Zone.

Additionally, according to the global distribution of temperate salt marshes, the deliberate choice of the study area aimed at representing the most comprehensive salt marsh habitat area along the Western Mediterranean coastal of Egypt. (30°48'15.4"–31°10'28.1" N, 27°39'58.6"–29°42'41.2" E) (Appendix S1, Figure 1).

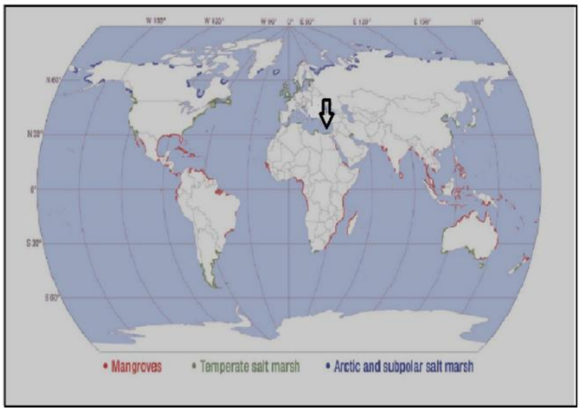

Figure 1. Global distribution of coastal wetland (Scott *et al.*, 2014), in which the arrow referring to the study area.

Data (2000–2020) obtained from NASA "https:// power. larc. nasa.gov/" showed that the average maximum temperature differs from 22 °C during January to 37 °C during June and July, while the average minimum temperature differs from 6.5 in January to 20.4 °C during July. The maximum values of precipitation were recorded during January with 0.8 mm, while there is no precipitation was recorded during May, June, July, August, and September (Figure 2).

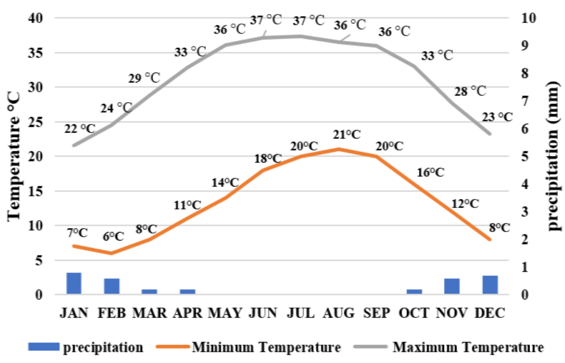

Figure 2. Climograph of monthly mean temperature as well as precipitation of the study area.

Floristic analysis

A vegetation survey to assess the ecological situation of extreme halophytic plant species between spatial locations was carried out in the year 2021. Fifty-four stands were carefully chosen to represent the variations in vegetation structure representing a halophytic environment along the salinity gradient perpendicular to the shoreline to about 6.5 km southward. Each site was 40 m × 40 m, estimated according to the minimal area. In each site, floristic records were described with the cover-abundance index (Braun-Blanquet, 1932). Based on voucher herbarium specimens and reference books, species were identified (Tackholm & Boulos, 1974; Boulos, 2009); the species nomenclature was improved using "https://wfoplantlist.org/plant-list". Species geographical distribution was conducted in order to determine the listed species into different geographical groupings worldwide (Eig, 1931).

Soil Analysis

From the 54 investigated stands, blended samples of soil were taken from the surface to a depth of 20 centimeters near naturally occurring plants. The following physical and chemical soil parameters were measured in each of the 54 stands: The soil texture was assessed according to (Miller, 1973). The measurement of electrical conductivity (EC) was conducted using a direct indicating conductivity bridge (ds\m). Soil pH was evaluated in soil extract of 1:5 for each sample as described by Fresenius *et al.* (1988). Organic Matter (OM %) was estimated using loss on ignition method (Sparks *et al.*, 1996). In addition, the soil's available nutrients of nitrogen, potassium, and phosphorus were determined in each stand's soil extract. The digested solution utilized in the determination of total nitrogen was created through the utilization of the Micro-Kjeldahl equipment. The element potassium (K) was analyzed using a flame photometer. In contrast, the spectrophotometer was utilized to determine the concentrations of phosphorus and nitrogen using the molybdenum blue and indo-phenol blue techniques, respectively. These procedures are measured following the procedure provided by Allen *et al.* (1974). The measurement of the amount of calcium carbonate ($CaCO_3$) was conducted by utilizing Collin's carbonate content calcimeter (Wright, 1934). The assessment of chloride ion was estimated using the process of titration with silver nitrate according to Jackson and Thomas (1960). The gravimetric method was employed to quantify the sulphate concentration (Piper, 1945). The concentration of sodium and potassium was assessed as detailed by Wild *et al.* (1979), whilst the atomic absorption spectrometer was used to determine calcium and magnesium ion content. Titration with Hydrochloric acid was applied to acquire bicarbonates (Pierce *et al.*, 1958). After Youssef (2009), the soil moisture content (SWC %) was determined. To assess the collective effects of various ions present in the soil, the sodium adsorption ratio (SAR) and potassium adsorption ratio (PAR) were determined as stated by (McKell & Goodin, 1984).

Where, SAR = $Na^+/\ [(Ca^{+2} + Mg^{+2})/2)]^{0.5}$. likewise, PAR has been defined with K^+ concentration replacing that of Na^+ (Levy & Feigenbaum, 1996).

Analysis of data

The aim of this part is to identify the connections among species, stands, and environmental conditions and the environmental factors that may influence species distribution. To achieve the above-mentioned targets, multivariate analysis were applied with Community Analysis Package (CAP) (Henderson & Seaby, 1999): for the Classification approach, Two-Way Indicator Species Analysis (TWINSPAN) was applied, while Detrended Correspondence Analysis (DCA) was utilized for the ordination. Canonical Correspondence Analysis (CCA) was employed to ascertain the association between vegetation and soil properties (Ter Braak, 1987). One-way analysis of variance (ANOVA) was utilized to evaluate the importance of variation in soil features (SPSS, 2006). In addition, The Pearson correlation coefficient (r) was computed in order to evaluate the possibility of a linear relationship between the two soil parameters; -1.0 to 1.0 was the range of its value, with the closer to +1, indicating a stronger positive linear relationship between the variables (Hair *et al.*, 1998).

RESULTS AND DISCUSSION

Vegetation characteristics

The results presented in this section provide an overall picture of the characteristic phytosociological features of 54 stands. It is first to be mentioned that the present study has documented a total of 165 plant species pertaining to 117 genera from 36 different families. Dicots were represented by 30 families and 131 taxa, while 6 families and 34 taxa represented monocots (Appendix S2). Accordingly, Dicotyledonous halophytes have greater salinity tolerance compared to monocotyledonous species (Shabala, 2013).

It is notable that most plant species associated with the Asteraceae, Poaceae, and Fabaceae families with 27 species each (16.36 % of the total species), and 21 species (12.73 %), respectively. Amaranthaceae and Caryophyllaceae were represented by 19 species (11.52 %) and 11 species (6.67 %), respectively. Apiaceae and Plantaginaceae comprising five species each (3.03 %), Brassicaceae comprising four species (2.42 %). Twelve families are represented by a range of 2 to 3 species. Meanwhile, 16 families exhibited poorly represented, having one single species each. The aforementioned families represent a significant proportion of the flora found in the Mediterranean North African region (Quézel, 1978). This result agrees with (Aronson & Whitehead, 1989) who reported that Asteraceae and Amaranthaceae represent the highest proportion of xerophytes and salt-tolerant genera and species in the Mediterranean region.

Regarding growth form, the majority of the documented species consisted of perennials, accounting for 89 species, which represent 53.94% of the overall species. This was followed by annuals, comprising 76 species (46.06 %). The most represented growth form was the perennials. It is consistent with numerous findings stating that the perennial halophytic species have been reported to be extremely salt-tolerant (Gulzar *et al.*, 2003; Shen *et al.*, 2003).

There were six different types of life forms documented. Generally, the most prevalent life form observed in the study was therophytes with 76 species and comprising 46.06% of the overall reported species. This subsequently came by chamaephytes (39 species = 23.64 %) then hemicryptophyte (29 species = 17.58 %) and phanerophytes (14 species = 8.48 %). However, geophytes (7 species = 4.24 %) and parasites exhibited the lowest level of representation among the various life forms (1 species = 0.61 %). The Percentage of species representing various life forms for the plant species recorded in the selected study area is shown in Figure 3.

The dominance of therophytes appears to be a result of their adaptation to the arid climate, topographical diversity, and biotic factors (Heneidy & Bidak, 2001). In addition, According to (Da Costa *et al.*, 2007), therophytes were identified as the prevailing life form arid regions, and they often account for about 40% of the species found in the Mediterranean area.

Chorological analysis revealed the profusion of the Mediterranean taxa with 113 species accounting for approximately 68.48% of the overall species. These taxa exhibit either Mono-regional (28 species = 16.97 %), Bi-regionals (39 species = 23.64 %) or Pluri-regionals (46 species = 27.87 %).

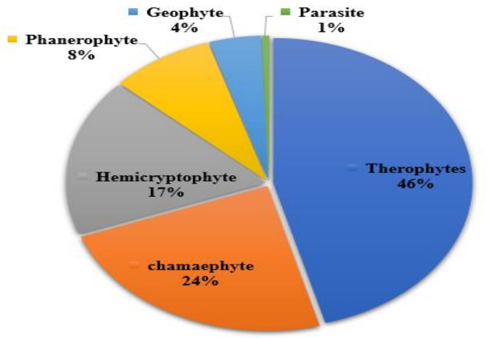

Figure 3. The documented species' life forms spectrum.

The Saharo- Arabian taxa comprised 81 species accounting for 49.09 % of the total species. These taxa were either Mono-regional (17 species = 10.30 %), Bi-regionals (31 species = 18.78 %) or Pluri-regionals (33 species = 20 %). On the other hand, the chorotype cosmopolitan, palaeotropical and pantropical was represented by 14 species (8.48 %), 2 species (1.21 %), and 3 species (1.81 %) respectively (Table 1).

Table 1. The species number and the proportion of each floristic category.

Chorotype	Number of species	Percentage (%)
Mono-regional		
MED	28	16.97
SA	17	10.30
IT	2	1.21
Sum	47	28.48
Bi regionals		
MED+SA	20	12.12
MED+IT	15	9.09
MED+ES	4	2.42
SA+IT	7	4.24
SA+SU	2	1.21
SA+SZ	2	1.21
IT+SZ	1	0.61
Sum	51	30.91
Pluri-regionals		
COSM	14	8.48
PAL	2	1.21
PAN	3	1.82
AUST	2	1.21
MED+IT+ES	13	7.88
MED+SA+IT	25	15.15
MED+SA+ES	2	1.21
MED+SA+SU	1	0.61
MED+SA+SZ	1	0.61
MED+SA+IT+ES	2	1.21
MED+SA+IT+SZ	2	1.21
Sum	67	40.61
Total	165	100

COSM: Cosmopolitan, PAL: Palaeotropical, PAN: Pantropical, MED: Mediterranean, SA: Saharo- Arabian, IT: Irano- Turanian, ES: Euro-Siberian, SU: Sudanian, SZ: Sudano-Zambezian, AUST: Australian.

The chorological assessment in the present investigation revealed the abundance of several Mediterranean and Saharo-Arabian components either pure or penetrated other regions. The current study's chorological research agreed that Egypt serves as a crossroads for flora from no fewer than four phytogeographical areas: African Sudano-Zambesian, Asian Irano-Turanian, Afro-Asian Sahro-Arabian, and Euro-Afro-Asian Mediterranean (El-Hadidi, 1993; Mashaly *et al.*, 2015). Species preeminence that penetrated other regions over the pure mono-regional ones refers to as The existence of inter-zonal habitats, such as man-made affected sites (El-Ghani *et al.*, 2013; El-Amier *et al.*, 2016). The high percentage of Saharo-Arabian chorotype plants may be linked to the observation that the plant species of the Saharo-Arabian region are highly suited to desert environments (El-Amier & Abdul-Kader, 2015; El-Zeiny *et al.*, 2022).

Multivariate analysis of stands

TWINSPAN classification on the floristic composition of the 54 stands divided the stands into four vegetation groups. These four distinct groups are presented in Figure 4 with the indicator species and the eigenvalues that are used by the software for every level of division. The nomenclature of these vegetative groupings was derived from the identification of the first and second dominating species and thereafter designated accordingly:

1- **Group (A):** *Arthrocnemum macrostachyum - Phragmites australis* (VG1); It comprises 12 stands and 61 species. The frequent species were *Avena fatua, Avena barbata,* and *Piptatherum miliaceum.* This group exhibited the highest level of biodiversity, as evidenced by its species richness (23.58), Despite the low species turnover in this group (β-diversity) (2.59). This group consisted of soil characterized by the largest proportions of silt and clay particles, calcium, and magnesium. And the lowest contents of sand particles %, soil water content (SWC) and potassium adsorption ratio (PAR). For more details, see Table 2 and 3.

2- **Group (B):** *Arthrocnemum macrostachyum - Halocnemum strobilaceum* (VG2); It comprises 13 stands and 37 species. Compared to other groups, this one had the lowest level of diversity in comparison to the other groups whereas species richness (11.23), and the species turnover equal to 3.29 (Table 2). The highest electrical conductivity belonged to this category (30.73 ds/m) in addition to pH (8.74), sodium (229.01 meq/l), and chloride (118 meq/l), while they had the lowest values of calcium carbonate (21.76 %) (Table 3). Among the abundant species are *Phragmites australis, Juncus rigidus, Tamarix aphylla,* and *Limoniastrum monopetalum.*

3- **Group (C):** *Phragmites australis - Limoniastrum monopetalum* (VG3); It comprises 22 stands and 121 species. Other significant indicator species are *Halocnemum strobilaceum*, *Imperata cylindrica*, and *Atriplex halimus*. The species richness of this group was 20.55 and this particular group exhibited the most significant species turnover. (β-diversity = 5.89). The soil samples obtained from these specific stands had the most elevated levels of organic matter (OM = 0.42 %) and magnesium (27.19 meq/l); but the lowest values of available nutrients of P, K (Table 2, 3).

4- **Group (D):** *Suaeda vermiculata - Salsola tetrandra* (VG4); It consists of 7 stands and 83 species. This group has a species richness of 21.71 and a species turnover of 3.82. These sites' soil had the highest sand % and calcium carbonate content but the lowest values for practically all soil factors as silt, clay, electrical conductivity, chloride, and sulfate content. Other notable species in this vegetation group are *Limoniastrum monopetalum, Plantago crypsoides*, and *Sporobolus pungens* (Table 2, 3).

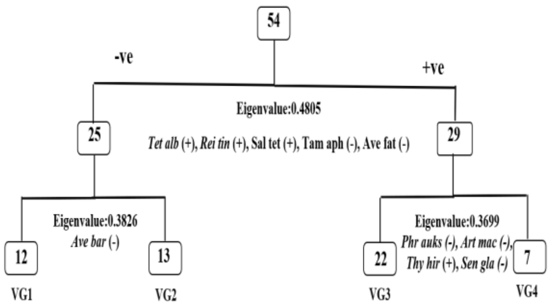

Figure 4. The dendrogram visually represents the TWINSPAN classification of the 54 stands within the designated study region. The four distinct vegetation groups were denoted as VG1, VG2, VG3, and VG4.

Detrended Correspondence Analysis (DCA) was used on the vegetation data from the research area, and the results showed the segregation of four vegetation types was clearly separated along the first two axes, and the findings were plotted into the DCA graph shown in Figure 5. The sites tend to cluster into the four vegetation categories outlined previously.

The current study's use of the TWINSPAN categorization approach on the sampled stands resulted in four vegetation groups. It can be highlighted that group B stands had the highest soil salinity, which was prevailing by *Arthrocnemum macrostachyum, Halocnemum strobilaceum, Phragmites australis,* and *Limoniastrum monopetalum*, as well as the least diversity and the most human impact when compared to other stands. This outcome aligns with the discoveries of Heneidy and Bidak (2004), who found that communities representing Salt marshes had lower levels of biodiversity compared to other ecosystems. These findings corroborate the conclusions of the current investigation. Also, according to Ghabbour (1984), with increased human interference through agricultural methods and more intense land use, there has been a reduction in diversity. These groups were clearly differentiated along DCA ordination axes, and it is worth noting that the above-mentioned vegetation groupings may have interspecific relationships due to similarities in floristic composition and ecological parameters.

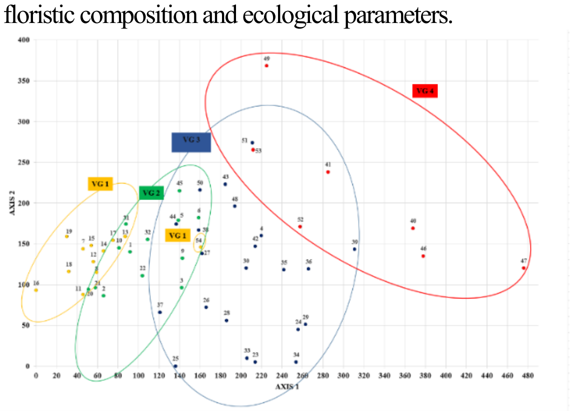

Figure 5. The DCA ordination representation depicts the distribution of the studied sites on axes 1 and 2.

Table 2. Characteristics and some calculated diversity indices of the ٤ vegetation groups of the floristic composition of 54 stands identified along the study area (P: presence percentage).

Cluster	No. of Stands	No. of Species	Species richness	Species turnover	First dominant	P %	Second dominant	P %
VG 1	12	61	23.58	2.59	*Arthrocnemum macrostachyum*	91.67	*Phragmites australis*	83.33
VG 2	13	37	11.23	3.29	*Arthrocnemum macrostachyum*	92.31	*Halocnemum strobilaceum*	53.85
VG 3	22	121	20.55	5.89	*Phragmites australis*	68.18	*Limoniastrum monopetalum*	86.36
VG 4	7	83	21.71	3.82	*Suaeda vermiculata*	85.7	*Salsola tetrandra*	85.7

Table 3. The mean ± standard deviation of different soil variables of the four vegetation groups identified in the current study.

Soil variable	TWINSPAN Vegetation Groups				F-value	p-value
	VG1	VG2	VG3	VG4		
Sand %	66.40 ± 4.23	82.66 ± 2.54	87.74 ± 1.42	93.01 ± 1.65	16.93***	0.000
Silt %	16.83 ± 2.68	9.69 ± 1.77	6.73 ± 0.93	2.86 ± 0.86	10.01***	0.000
clay %	17.18 ± 2.81	7.80 ± 0.96	5.53 ± 0.71	4.14 ± 1.41	13.71***	0.000
PH	8.27 ± 0.12	8.74 ± 0.04	8.61 ± 0.07	8.59 ± 0.13	4.6**	0.006
EC (dS/m)	23.64 ± 3.77	30.73 ± 4.46	12.09 ± 2.86	4.17 ± 2.24	8.52***	0.000
OM %	0.23 ± 0.02	0.33 ± 0.05	0.42 ± 0.09	0.23 ± 0.04	1.55^{ns}	0.214
CaCO3 %	35.74 ± 5.34	21.76 ± 4.29	26.89 ± 3.49	39.4 ± 8.21	2.29^{ns}	0.089
Ca^{+2} (mEq/L)	20.98 ± 2.75	19.88 ± 4.30	12.39 ± 2.11	8.75 ± 4.29	2.83*	0.048
Mg^{+2}(mEq/L)	69.78 ± 11.25	62.36 ± 12.01	27.19 ± 4.97	30.31 ± 19.23	4.98**	0.004
Na^{+} (mEq/L)	160.86 ± 27.81	229.01 ± 37.28	70.73 ± 17.43	10.46 ± 2.49	11.31***	0.000
K^{+}(mEq/L)	6.27 ± 1.36	8.6 ± 1.77	4.41 ± 1.02	1.24 ± 0.32	3.89*	0.014
$HCO3^{-}$ (mEq/L)	4.18 ± 1.05	3.05 ± 0.46	2.74 ± 0.50	1.16 ± 0.22	2.35^{ns}	0.084
Cl^{-} (mEq/L)	148.8 ± 47.68	118 ± 19.05	36.35 ± 8.23	27.6 ± 16.97	5.69**	0.002
$SO4^{-2}$(mEq/L)	51.48 ± 9.54	50.13 ± 7.91	36.08 ± 5.61	8.22 ± 3.13	4.66**	0.006
N (mg/Kg)	5.09 ± 0.82	5.53 ± 0.99	4.07 ± 0.96	3.27 ± 0.87	0.77^{ns}	0.514
P (mg/Kg)	17.40 ± 2.15	19.64 ± 2.97	10.58 ± 1.14	11.31 ± 3.65	4.52**	0.007
K (mg/Kg)	1037.50 ±141.84	807.69 ± 99.01	479.55 ± 65.11	496.43 ± 139.88	6.85**	0.001
SWC %	10.91 ± 2.03	11.03 ± 2.15	11.90 ± 1.42	14.69 ± 2.35	0.52^{ns}	0.670
SAR	23.26 ± 2.83	38.09 ± 6.28	14.25 ± 2.98	3.55 ± 1.09	10.24***	0.000
PAR	0.97 ± 0.18	1.61 ± 0.43	0.96 ± 0.18	0.38 ± 0.09	2.57^{ns}	0.065

Correlation of Plant Community and Soil parameters

The soil-vegetation relationship was established by the implementation of Canonical Correspondence Analysis as shown in figure 6, indicated that soil texture, salinity (EC), sodium, potassium ion, sulphate, and sodium adsorption ratio (SAR) were the most influenced variables. It can be noted that almost all the factors affecting salinity are correlated with each other, especially electric conductivity, and sodium ions.

The distribution of the dominating species, *Arthrocnemum macrostachyum*, was shown to be highly correlated with salinity and sodium ion content. Furthermore, *Phragmites australis* and *Suaeda vermiculata* were shown to be closely related to the percentage of clay and $CaCo_3$ (figure 6).

Variation in the examined edaphic factors within the separated vegetation groups was detected as shown in Table 3. The major soil variables significantly affecting plant distribution are electrical conductivity, soil texture, sodium adsorption ratio, and sodium ion content (Table 3). Other soil factors do not have a significant correlation such as bicarbonate, PAR, OM %, SWC %, and calcium carbonate percentage. This finding is consistent with previous research that found that high electric conductivity and other salinity characteristics were the most critical factors related to the distribution of halophytic plant species. Furthermore, soil salinity can influence the community structure and diversity of wild communities (Liangpeng *et al.*, 2007; Andreasen & Skovgaard, 2009; Pinke *et al.*, 2010).

In addition, the correlation matrix between the various edaphic parameters in the sample stands is given in Figure 7. Electrical conductivity has a strong positive linear relationship with nearly all salinity parameters such as sodium, chloride, magnesium, sulphates, and sodium adsorption ratio. Both calcium ion and silt fraction depict a high positive correlation with available nutrients of potassium, salinity, sodium, magnesium, and chloride ions. Furthermore, some parameters, such as the proportion of SWC, $CaCo_3$, OM, soil texture, and pH, exhibit a negative or no correlation with other edaphic factors (Figure 7).

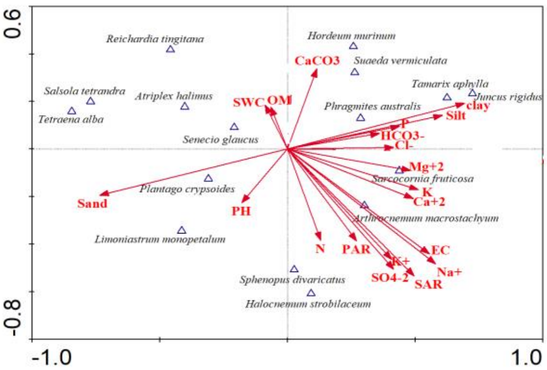

Figure 6. The biplot of canonical correspondence analysis illustrates the arrangement of the indicator species and their associations with the environmental variables.

Soil variables	Sand	Silt	clay	PH	EC	OM	CaCO3	Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	$HCO3^{-}$	Cl^{-}	$SO4^{-2}$	N	P	K	SWC	SAR	PAR
Sand	1																			
Silt	-0.885**	1																		
clay	-0.882**	0.567**	1																	
PH	0.435**	-0.401**	-0.368**	1																
EC	-0.348**	0.455**	0.170	0.006	1															
OM	0.103	-0.103	-0.088	0.183	-0.119	1														
CaCO3	0.044	-0.089	0.009	-0.312*	-0.145	0.045	1													
Ca^{+2}	-0.278*	0.331*	0.182	0.013	0.615**	-0.185	-0.032	1												
Mg^{+2}	-0.357**	0.428**	0.226	-0.062	0.707**	-0.173	0.041	0.740**	1											
Na^{+}	-0.330*	0.432**	0.151	-0.024	0.913**	-0.078	-0.156	0.513**	0.597**	1										
K^{+}	-0.194	0.267	0.093	0.198	0.693**	0.090	-0.156	0.273*	0.326*	0.647**	1									
$HCO3^{-}$	-0.350**	0.323*	0.286*	-0.555**	0.289*	-0.032	0.048	0.261	0.248	0.270*	0.003	1								
Cl^{-}	-0.529**	0.711**	0.223	-0.344*	0.656**	-0.102	0.056	0.502**	0.652**	0.600**	0.276*	0.480**	1							
$SO4^{-2}$	-0.194	0.231	0.123	0.124	0.682**	0.010	-0.119	0.452**	0.353**	0.642**	0.698**	0.068	0.210	1						
N	-0.101	0.186	-0.010	-0.001	0.245	-0.035	-0.286*	0.139	0.078	0.270*	0.225	0.093	0.149	0.266	1					
P	-0.170	0.076	0.234	0.030	0.260	0.002	-0.082	0.213	0.220	0.296*	0.159	-0.033	0.107	0.247	0.058	1				
K	-0.458**	0.465**	0.370**	-0.012	0.624**	-0.122	-0.099	0.418**	0.540**	0.525**	0.671**	0.081	0.383**	0.571**	0.257	0.292*	1			
SWC	-0.066	0.001	0.105	-0.109	0.095	-0.045	-0.128	-0.074	-0.090	0.082	0.099	0.040	-0.037	0.071	-0.044	-0.008	0.017	1		
SAR	-0.257	0.317*	0.132	-0.051	0.794**	-0.039	-0.174	0.270*	0.339*	0.923**	0.695**	0.244	0.426**	0.630**	0.328*	0.274*	0.455**	0.168	1	
PAR	-0.106	0.133	0.057	0.196	0.429**	0.154	-0.152	-0.019	0.009	0.434**	0.913**	-0.055	0.079	0.525**	0.150	0.073	0.474**	0.107	0.599**	1

Figure 7. The matrix of Pearson's correlation (r) between the soil variables in the stands assessed in the study region.

CONCLUSION

Based on the findings of this study, it can be inferred that salinity is the most edaphic factor that influences the distribution of halophytic species, community structure, and wild community diversity. Halophytes, which represent a viable economic resource, are under threat from unmanaged human activity. As most of the seaward area has been completely degraded except for small patches of free water dominated by *Phragmites australis* and *Typha latifolia*, there is no possibility of rehabilitation. Therefore, steps should be taken to preserve the ecological and economic circumstances of halophytic ecosystems against unrestricted land usage that contributes to the squandering of land and environmental degradation.

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العوامل البيئية المؤثرة على التوزيع المكاني للنباتات الملحية فائقة التحمل على الساحل الشمالي الغربي للبحر الأبيض المتوسط في مصر

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الملخص

يمارس تغير المناخ تأثيرا كبيرا على النظم الإيكولوجية الساحلية ، في المقام الأول من خلال ارتفاع منسوب مياه البحر ، والتي تشكل تهديدا عالميا للمستنقعات المالحة ، والموائل الأساسية لأنواع النباتات الملحية القيمة. في الوقت نفسه ، تشكل الأنشطة البشرية غير الخاضعة للرقابة أيضا خطرا كبيرا على النباتات الملحية. وبالتالي ، فإن فهم العوامل التي تشكل تنوع المجتمعات النباتية وتوزيعها يصبح محوريا لحفظ التنوع البيولوجي واستعادة الغطاء النباتي المتدهور. ولمعالجة ذلك، اخترنا ٥٤ منصة عبر الساحل الشمالي الغربي للبحر الأبيض المتوسط في مصر، تشمل تدرج الملوحة، مما يعكس التوزيع العالمي للمستنقعات المالحة المعتدلة. تم جمع عينات التربة عبر هذه المواقع ال ٥٤ لإجراء تقييمات شاملة لمعلمات التربة. كان يسكن المنطقة المدروسة ١٦٥ نوعا ، موزعة على ١١٧ جنسا و ٣٦ عائلة. العائلات الأكثر وفرة من حيث الأنواع هي Asteraceae و Poaceae و Fabaceae و Amaranthaceae. و كانت Therophytes هي من أكثر أشكال الحياة الممثلة. تم تطبيق تحليل متعدد المتغيرات لتحديد العناصر البيئية التي قد يكون لها تأثير على توزيع الأنواع. بعد استخدام TWINSPAN و DCA كنهج للتصنيف والتنسيق ، ظهرت أربع مجموعات نباتية. و وجد ان حالة الملوحة تؤثر على توزيع الأنواع الملحية وهيكل المجتمع وتنوع المجتمع البري. ومع تصاعد التدخل البشري في العمليات الزراعية وتكثيف استخدام الأراضي، تدهورت المنطقة الساحلية بالكامل باستثناء بقع صغيرة ولا توجد إمكانية لإعادة تأهيلها .ونتيجة لذلك، ينبغي اتخاذ خطوات للحفاظ على موائل المستنقعات المالحة ضد الاستخدام غير المقيد للأراضي.

الكلمات الدالة: النباتات فائقة الملوحة ، النظم الإيكولوجية الساحلية، العوامل البيئية، ملوحة التربة.