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Hyperspectral Remote Sensing of Floristic Composition and Phytogeographical Distribution in Gebel El-Sibaie, El-Quseir, Egypt

Nessrien M. Hamad-Allah [*1,2], Amal A. Morsy[1], El-Sayed A. Khalifa[2], Ghada A. Khdery[3], Mahmoud E. Ali[2], Maged M. Abutaha[2]

[1] *Faculty of Science, Ain Shams University (ASU), Cairo, Egypt.*
[2] *Department of Plant Ecology and Range Management, Desert Research Center (DRC), Cairo, Egypt.*
[3]*Department of Agriculture application, Soils and Marine, National Authority for Remote Sensing and Space Science (NARSS), Cairo, Egypt.*
*Corresponding author: Nessrien M. Hamad-Allah (nessrien2023@gmail.com)
[1]Amal A. Morsy, *ASU* (amalmorsy@sci.asu.edu.eg).
[2]El-Sayed A. Khalifa, DRC (info@drc.gov.eg).
[2]Mahmoud E. Ali, DRC (mdsw78@hotmail.com).
[2]Maged M. Abutaha, DRC (maged_abutaha@yahoo.com).
[3]Ghada A. Khdery, NARSS (ghada.ali@narss.sci.eg).

Abstract

Our study aims to explore the flora of the Gebel El-Sibaie and utilizes hyperspectral remote sensing to enhance the assessment of plant diversity. We analyze vegetation elements, including floristic diversity, life form, lifespan, and phytogeographical affinities, and utilize hyperspectral remote sensing with an ASD spectroradiometer. A total of 60 species belong to 49 genera and 29 different families, with Fabaceae, Zygophyllaceae, and Asteraceae being the most characteristic families. The flora exhibits high monotypism, with 40 genera and 19 families. Chamaephytes and therophytes are the most prevalent life forms. The common lifespan was for perennials. Acacia cyclocarapa, Leucaena leucocephala, and Prosopis juliflora were recorded as alien species for the first time in Al-Quseir. Phytogeographical analysis reveals that mono-regional elements are the most dominant chorotypes, with Saharo-Arabian taxa comprising approximately a quarter of the floristic structure. The study created a spectral library of 37 plants and soil samples from 22 sites. It found consistent spectral signatures across plants, especially in the visible and infrared regions. Phragmites australis, Leucaena leucocephala, and Paronychia argentea had higher reflectance. Furthermore, plants manage water stress differently, with higher visible reflectance associated with increased chlorophyll content and lower infrared reflectance resulting from water absorption. Soil properties like coarse sand enhance reflectance in the visible and NIR regions, while silt and clay boost absorption in the SWIR. Chemical factors, such as EC and mineral content, impacted spectral signatures.

Keywords: *Arid desert, Chorology, Diversity, Eastern Desert, life form, invasive, Red Sea, Spectral Signature*

1. Introduction

The Eastern Desert of Egypt, extending eastward from the Nile Valley to the Red Sea and the Gulf of Suez, comprises 21% of Egypt's total land area. Moreover, comprises the backbone of high, rugged mountains parallel to the Red Sea coast. Its major phytogeographical regions are the Red Sea coastal region and the inland Sahara (Zahran & Willis, 2009). The Egyptian

desert, with its arid and/or extremely arid climate, exposes vegetation to harsh and drastic environmental circumstances (Batanony, 1979; Zahran & Willis, 2009).

Desert vegetation was classified into three categories: a permanent framework of perennials, ephemerals, and accidental species, which are characterized by low and erratic rainfall, the likelihood of rainy seasons, and soil thickness, which affects the appearance and lifespan of ephemerals (Kassas, 1952, 1966, 1971). Ephemerals, annuals, and biennial plants become drier with the arrival of a lengthy summer rainless season (Boulos, 2005). Perennials, a common framework for desert plants and a good predictor of habitat conditions (Zahran & Willis, 2009), are classified into five groups: xerophytes, halophytes, psammophytes, helophytes, and mangroves (Zahran & El-Amier, 2014). Perennial xerophytes, drought-resistant shrubs, and under shrubs are the most significant and distinctive plant life in the Egyptian desert (Zahran & Willis, 2009).

Desert vegetation exhibits significant variation in species distribution with minimal irregularities in physiographic factors, making it an interesting and informative aspect of plant ecology (El-Khouly & Shawky, 2017). Vegetation structure, floristic composition, and life form spectrum are crucial for ecological studies. They are demonstrated through vertical species stratification, spatial distribution of individuals, and species abundance (Barnes *et al*., 1998; Abutaha *et al*., 2021).

Biotic, abiotic, historical, and human influence plant distribution and abundance (Wisz *et al*., 2013). However, disturbance has been accelerated according to excessive irresponsible anthropogenic interventions, harsh habitat conditions, climate change, and invasive species. As a result, deterioration of desert wildlife population dynamics, threaten biodiversity, disrupt natural habitats, and rapidly deplete natural vegetation in arid regions (Hegazy *et al*., 2004a, 2007; Alhammadi, 2010; Halmy *et al*., 2019; Mahklouf, 2019; Bedair *et al*., 2021; Hussein *et al*., 2021; Abbas *et al*., 2023; Haq *et al*., 2024).

Egypt is divided into three floral provinces: (1) Saharo-Sindian Province "includes most of Egypt's deserts"; (2) The Iranian Turanian "includes the mountainous region of South Sinai and the Galala Mountains of the Eastern Desert"; (3) The Sudano-Zambezian "includes the Gebel Elba region in southeastern Egypt" (Eig,1931-1932). Most of Egypt's deserts are within the Sahara Regional Transition Zone, except for the Western Mediterranean coastal zone and the Gebel Elba region, which are part of the Sahel region (White, 1993).

The hyperspectral technique offers a range of absorption measurements from narrow spectral bands to distinguish between different plants based on their spectral signatures (Nagendra, 2002). The reflectivity of plant features is associated with biological substances that are present in the leaves, and the physical attributes of the leaves, including the air-water interfaces and air-space fraction. Plant physiology, morphology, or anatomy provides the basis for a species' spectral characteristics (Jarocinska *et al*., 2016; Kycko *et al*., 2014). It is possible to compute, record, and assign even slight variations in reflectance to specific plants, enabling the classification of species based on their spectral characteristics. In this manner, species-specific spectral characteristics were identified using contrasting spectral reflectance patterns (Kupková *et al*., 2017; Marcinkowska *et al*., 2017). Khdery *et al*. (2014); Aboelghar and Khdery (2017); Khdery *et al*. (2019); Yones (2019); Gamal *et al*. (2020), and others are just a few examples of the various applications of multispectral and hyperspectral data in Egypt, including vegetation cover discrimination and vulnerability assessments.

The present study was designed to investigate the current status of the floristic composition in the Gebel El-Sibaie area, encompassing mountains and wadis distributed throughout the

study area. It compares the present status of flora with earlier records and relevant studies, recognizing life forms and chorological distribution of the vegetation. The study utilized hyperspectral remote sensing, employing an ASD spectroradiometer, to enhance the assessment of plant diversity and distribution patterns within this unique environment.

2. Materials and methods

2.1. Study area

The Study area is a part of the hyper-arid Eastern Desert of Egypt. It is situated nearly in the middle part of the Eastern Desert, South-West of Al-Quseir city by about 30 Km, and located between latitudes 25° 30\ and 25° 45\ N and longitudes 34° 0\ and 34° 30\ E. It consists of mountainous belt started at the north at Gebel El-Sibaie, Gebel Umm lasifa, and Gebel Umm Naqqat, and their main drainage systems, from north to south, namely: Wadi Esel, Wadi Sharm El-Bahari, and Wadi Umm Gheig, to the coastal salt marshes at the Red Sea coast. (Fig. 1).

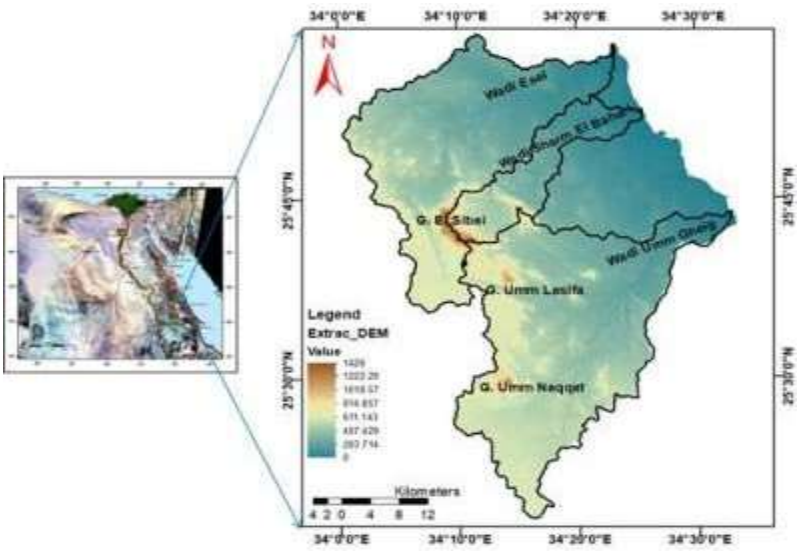


Fig. 1. Location map of the study area showing the studied three mountains (Gebel El-Sibaie, Gebel Umm lasifa, & Gebel Umm Naqqat) and their main Wadis (Esel, Sharm El-Bahary and Umm Gheig)

2.2. Floristic composition

The fieldwork was conducted during 2021, 2022, and 2023 through several trips. A total of 124 vegetation stands were randomly chosen, based on the diversity and variation of habitat types in the study area. For every stand, the species composition was listed. Plant species nomenclature and identification followed Täckholm (1974) and were updated according to Boulos (1999, 2000, 2002, 2005, 2009). The annual and perennial (life span) species were listed. The plant life forms are identified according to Raunkiaer (1934). The phytogeographical affinities of the surveyed species were defined as in previous studies on the Eastern Desert of Egypt (Zohary, 1973; Wickens, 1976; Abd El-Ghani *et al.*, 2017).

2.3. Soil sampling and analysis

Mixed soil samples were collected from the surface layer (0-20 cm) for each stand, air-dried, sieved through a 2 mm sieve to remove gravel and debris, and then packed to be ready for

analysis. Physical and chemical analyses of soil samples were carried out according to (Richards, 1954; Jackson,1962; Krumbein & Sloss, 1963; Allen et al.,1974; Ryan et al.,1996; ASTM, 2002).

2.4. Spectroscopic Analyses

The reflectance of 37 plant leaves was measured in the field using the ASD Field Spec. Spectrum reflectance curves were used to visually verify the vegetation spectrum reflectance qualities after the data was saved to an ASCII file using the statistical analysis application ASD View Pro. A statistical analysis identified the spectral bands that best distinguish the plants under investigation. The selection of bands was carried out using linear discriminant analysis (LDA) (Clark et al., 2005), and the effectiveness of the chosen wavelengths and bands in differentiating plant species was examined using ANOVA (Anderson, 2001).

3. Results

3.1. Floristic Diversity

A total of 60 plant species belonged to 49 genera, and 29 different families were recorded in the total study area; they were made up of 41 perennials (68.33%) and 19 annuals (31.67%) Appendix 1, Fig. (2). Among them three species (about 5.00 %) of the total surveyed flora have been recorded for the first time and represent new additions to the flora of Al-Quseir region; which are: *Acacia cyclocarapa*, *Leucaena leucocephala*, and *Prosopis juliflora*. These new records pertain to invasive taxa within the family Fabaceae (Appendix 1). Moreover, one species is considered endangered in Egypt (*Moringa peregrina*).



Fig. 2. Life cycle spectrum of the total flora recorded in the Gebel El-Sebaie area.

The species–rich families were Fabaceae (11 species, 18.33%), Zygophyllaceae (7 species, 11.67%), and Asteraceae (5 species, 8.33%) in the total study area, followed by Caryophyllaceae, represented by four species (6.67%). Meanwhile, Cleomaceae and Poaceae were represented by three species each (5.00%). Asclepiadaceae, Boraginaceae, Capparaceae, and Resedaceae exhibited the same number of recorded species (2 species=3.33% each). On the other hand, 18 families were poorly represented, having only one species each (1.67%) (Fig. 3).

The most characteristic families in the study locations were Fabaceae in both the Wadi bed of Umm Gheig (18.75%) and Esel (26.92%), and Zygophyllaceae at G. El-Sibaie, G. Umm-

Nakkat, and the Wadi bed of Sharm-El-Bahary (18.52%, 13.79%, and 25%, respectively). Gebel Umm Lasifa is the lowest location, comprising four families, each with one species (25%), namely Resedaceae, Moringaceae, Fabaceae, and Capparaceae (Appendix 1).

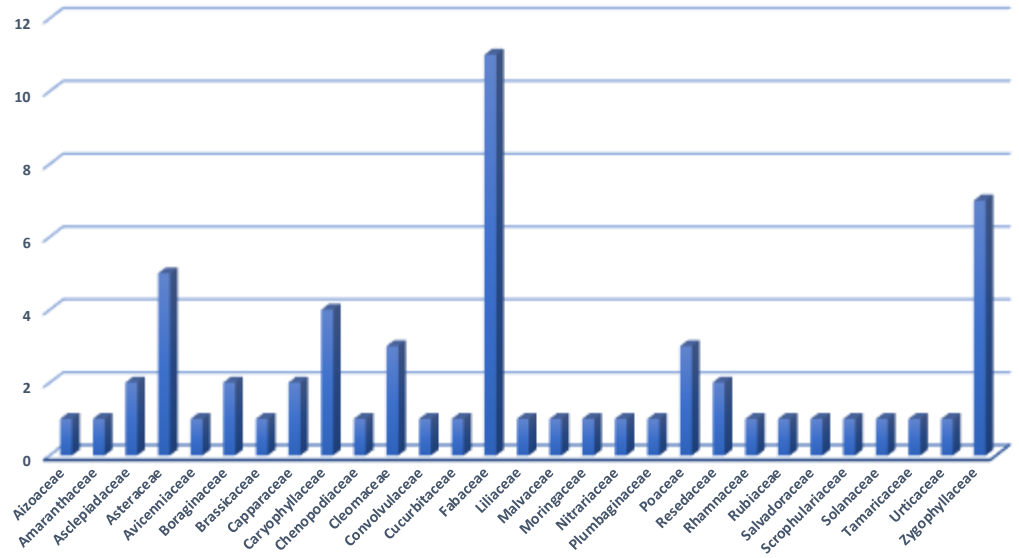


Fig. 3. Floristic composition of the 29 plant families recorded in the Gebel El-Sebaie area.

The largest families in terms of the number of genera in the total study area were Fabaceae (7 genera), Asteraceae, Caryophyllaceae & Zygophyllaceae (4 genera each) and Poaceae (3 genera). Meanwhile, the genera with the most significant number of species were *Acacia* L. with four species (6.67%), *Cleome* and *Zygophyllum* with three species each (5.00%), *Pulicaria*, *Capparis*, *Astragalus*, and *Fagonia* with two species each (3.33%). On the other hand, the other genera comprise the lowest number, one species each (1.67%).

The study clearly showed that the slope of mountains support vegetation growth of about 36 plant species. The main plant communites are: by *Acacia tortillis, Capparis cartilaginea, Cleome droserfoila, Leptadenia pyrotechnica, Lycium shawii, Moringa peregrina, Ochradenus baccatus, Reseda pruinose, Tephroisa apollinaea,* and *Zygophyllum simplex*. Open desert is characterized by 41 species, and is dominated mainly by *Zilla spinosa, Zygophyllum coccineum, Acacia tortilis, Balanites aegyptiaca, Capparis cartilaginea, Cleome droserfolia, Reseda pruinosa* (Appendix1). Mangrove vegetation is characterized by only one species *Avicennia marina*, and salt marsh vegetation including about 14 species *Nitraria retusa, Limonium axillare, Phragmites australis, Salsola imbricata, Tamarix nilotica, Taverniera aegyptiaca,* and *Zygophyllum album*. Overall, Gebel Umm Lasifa was the least diverse among the studied area.

3.2. Life form

Plant life forms of the study area were summarized at Fig. 4 there are five life forms were recorded. Chamaephytes (Ch) & Therophytes (Th) were the dominant life forms each represented by 30.00% of the total number of flora, most common species were *Zilla spinosa (L.), Capparis sinaica Veil., Cleome droserifolia (Forssk.), Fagonia mollis Delile Zygophyllum coccineum L* & *Cometes abyssinica* R.Br., *Reseda pruinose* Delile, *Zygophyllum simplex* L. *Tribulus terrestris* L and *Aizoon canariense* L. Followed by Phanerophytes (Ph) which comprises around 28.33% of the recorded species, of which *Avicennia marina* (Forssk.), *Leptadenia pyrotechnica*

(Forssk.), *Acacia tortilis subsp. raddiana* (Savi), *Acacia tortilis* (Forssk.), *Lycium shawii* Roem., *Moringa peregrina*, *Ochradenus baccatus*. Hemicryptophytes account for approximately 10.00% of the vegetation and included 6 species *Trichodesma ehrenbergii* Schweinf, *Phragmites australis* (Cav.), *Citrullus colocynthis* (L.), *Kickxia acerbiana*(Boiss.),*Forsskaolea tenacissima* L. and *Polycarpaea repens* (Forssk.).

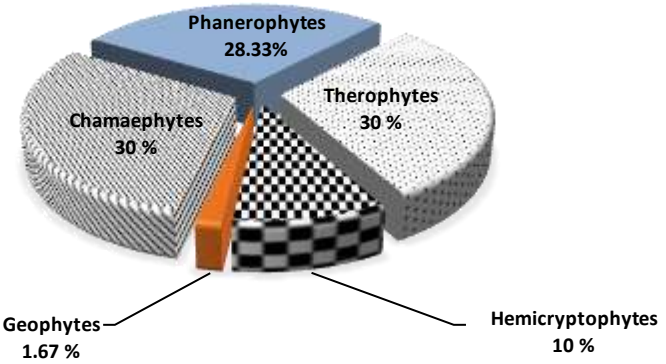


Fig. 4. Life form spectrum of the total flora recorded in the Gabal El-Sebaie area.

On the other hand, the lowest life form recorded is Geophytes (1.67 %) represented only by one species (*Panicum turgidum* Forssk.).

Fig.5 shows that Phanerophytes and chamaephytes were the most represented life forms in all study sites, with a high presence of (30.23 and 24.44%) at Wadi Esel and G. Umm-Naqqat, respectively, and a low presence (4.65 and 2.22% respectively) at Wadi Sharm El-Bahary and G. Umm Lasifa (no other life forms have been recorded at this location).

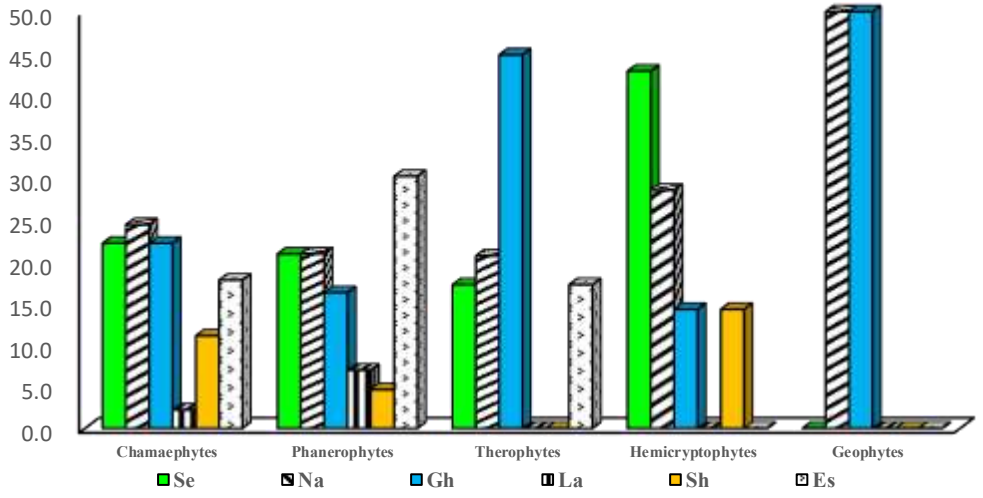


Fig. 5. Life form histogram and percentage of species at 6 study area locations: Gebel El-Sibaie (Se), Gebel Umm lasifa (La), Gebel Umm Naqqat (Na), Wadi Esel (Es) , Sharm El-Bahary (Sh) and Umm Gheig (Gh).

Therophytes prevail (44.83%) at Wadi Umm-Gheig, while they are absent from Wadi Sharm El-Bahary and G. Umm-Lasifa. The highest value of Hemicryptophytes (42.86%) was recorded at El-Sebaie Mountain. On the other hand, Geophytes were reported only at Wadi Umm-Gheig and Umm Naqqat Mountain with equal percentage (50% each).

3.3. Chorology

According to phytogeographical affinities, the total recorded species were classified into three major phytogeographical groups: monoregional, bioregional and pluriregional, in addition to, pantropical and Afro-Montane species (Table 1 & Fig. 6). Monoregional elements were the highest (29 species = 48.33%) among the surveyed species in the study area with different affinities, and fall under five main chorotypes: Saharo-Arabian had a wide geographical range (15 species accounting 25.00%); Saharo-Sindian (6 species forming 10.00%); Sudano-Zambezian (3 species forming 5.00%); the last two chorotypes were Sudanian & Medeterranian represented only by one species (*Acacia ehrenbergiana* Hayne & *Paronychia argentea* Lam.) each forming 1.67 %. Two American taxa, *Leucaena leucocephala* and *Prosopis juliflora*, represent 3.33%. One Australian taxon (*Acacia cyclocarpa*), representing 1.67%.

Twenty-two species of all recorded species (36.76%) were biregional taxa, and fall under four chorotypes: the Saharo-Arabian/Sudano-Zambezian chorotypes together had the highest share of 13 species (21.67%), Saharo-Arabian/Irano-Turanian regions, represented by seven species (11.67%). At the same time, Saharo-Arabian/Sudanian & Mediterranean/Saharo-Arabian regions have only one species (1.67% each), *Capparis decidua*, and *Phoenix dactylifera* L., respectively.

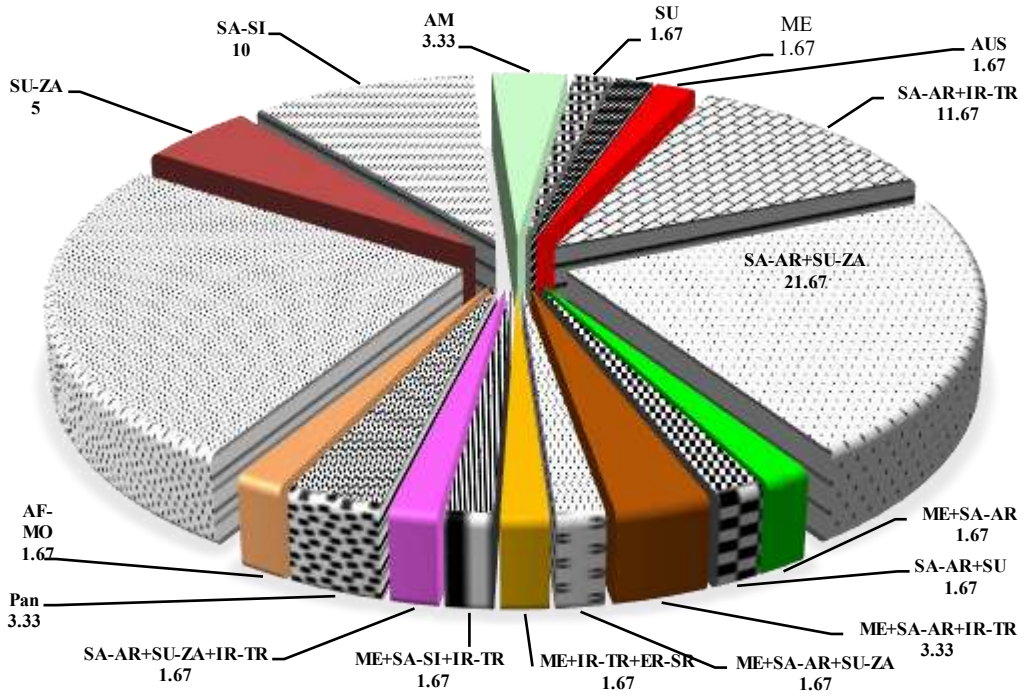


Fig. 6. Phytochorion categories of the total recorded species and their relevant percent in the Gebel El-Sebaie area. (Am= American, AUS=Australian, SA-AR= Saharo- Arabian, SU-ZA= Sudano-Zambezian, ME= Mediterranean, IR-TR= Irano-Turanian, Pan = Pantropical, AF-MO = Afro-Montane, SU=Sudanian, ER-SR = Euro–Siberian and SA-SI= Saharo-Sindian).

The pluriregional elements were represented by a total of 6 species (10.00%) of different affinities, which fall under five main chorotypes: Mediterranean/Saharo-Arabian/Irano-Turanian, with the highest share (2 species, forming 3.33%). At the same time, the other four chorotypes are Mediterranean / Saharo-Arabian/ Sudano Zambezian, Mediterranean/Saharo-Sindian/Irano-Turanian,Mediterranean/Irano-Turanian/Euro-Siberian, and Saharo-Arabian/Sudano Zambezian/Irano-Turanian. Only one species each (forming 1.67% of recorded species). The three remaining species were distributed among two species (3.33%) of the Pantropical chorotype (Phragmites australis (Cav.) and Tribulus terrestris L.) and one species of the Afro-Montane (*Cometes abyssinica* R. Br.), forming 1.67%

Table 1. The number of recorded species belonging to the main floristic chorotypes and their relevant percent (%) in Gebel El-Sebaie area. Phytochoria categories (Am= American, AUS=Australian, SA-AR= Saharo- Arabian, SU-ZA= Sudano-Zambezian, ME= Mediterranean, IR-TR= Irano-Turanian, Pan = Pantropical, AF-MO = Afro-Montane, SU=Sudanian, ER-SR = Euro–Siberian and SA-SI= Saharo-Sindian).

Phytochoria categories	No. of plant species	Percentage (%)
Monoregional		
AUS	1	1.67
AM	2	3.33
SU	1	1.67
ME	1	1.67
SA-AR	15	25.00
SU-ZA	3	5.00
SA-SI	6	10.00
Total	29	48.33
Bioregional		
ME + SA-AR	1	1.67
SA-AR + SU	1	1.67
SA-AR + SU-ZA	13	21.67
SA-AR +IR-TR	7	11.67
Total	22	36.67
Pluriregional		
ME+SA-AR+IR-TR	2	3.33
ME+SA-AR+SU-ZA	1	1.67
ME+IR-TR+ER-SR	1	1.67
ME+SA-SI+IR-TR	1	1.67
SA-AR+SU-ZA+IR-TR	1	1.67
Total	6	10.00
Others		
Pan	2	3.33
AF-MO	1	1.67
Total	3	5.00

3.4.Soil properties

Physical and chemical analysis of the soil of the study area were represented in Appendices (2&3). The results of granulometric analysis showed that the soil texture was primarily defined by a high percentage of very coarse and coarse sand at the slopes of the mountains, i.e., Gebel Umm Nakkat, Umm Lasifa, and El-Sibaie. Open deserts were characterized by delicate and very fine sand with high percentage at wadi Esel (24.43, 45.85% respectively). While, mangrove habitat was characterized by high percentage of Silt & Clay at Wadi Sharm El-Bahary, followed by salt marshes habitat (37.69 %) at wadi Esel (Appendix 2).

The soil particle size distribution across the surveyed mountain and wadi sectors reveals a

highly significant geomorphological segregation (F very coarse = 180.18, F silt & clay = 164.56; $p < 0.05$), where steep mountain slopes are dominated by residual, skeletal substrates rich in very coarse sand, peaking at 75.75 % ± 5.05 % on Umm Naqqat. In contrast, the low-lying wadi beds act as dynamic alluvial depositional channels. They exhibit highly heterogeneous sediment sorting influenced by the high-velocity energy of ephemeral flash floods, accumulating significantly larger proportions of fine and very fine sand fractions—such as the 38.58 % ± 4.28 % very fine sand observed in the El-Sebaie wadi beds. Moving toward the coast, the mangrove habitat of Wadi Sharm El-Bahary marks the final depositional extreme of these drainage networks,it sequesters the highest concentrations of silt & clay (41.44 % ± 4.60 %) and very fine sand (25.05 % ± 2.78 %), while retaining minimal coarse fragments (2.77 % ± 0.18 %) **Appendix (2).**

For chemical analysis, the soils of the study area were characterized as slightly acidic to alkaline, with the mean pH value ranging from 6.26 to 9.00, the EC ranges between (0.20–25.70 mS/m) Appendix (3). The mangrove habitat recorded the highest EC, followed by halophytic habitat, and wadi bed of wadi Umm Gheig (9.50, 6.69, respectively), while the slope of Gebel El-Sibaie records the lowest EC (0.22). TDS, and most mineral contents; i.e., Ca^{++}, Mg^{++}, Na^{+}, $HCO3^{-}$, $SO4^{-2}$, and Cl^{-} were high at Wadi Sharm El-Bahary. In contrast, P record the highest value at wadi bed of Gebel El-Sebaie.

The soil hydrochemical profile across the surveyed locations reveals extreme spatial divergence across topographical gradients, supported by exceptionally high F-values across all parameters (F TDS = 7,785,170.8, F EC = 1,391.75, F pH = 3,434.99; $p < 0.05$). Mountain slopes (El-Sebaie, Umm Lasifa, and Umm Naqqat) represent highly leached, oligotrophic regimes characterized by low electrical conductivity (EC ≤ 0.70 dS/m), minimal total dissolved solids (TDS ≤ 251.00 mg/L), and moderate alkalinity (pH 8.16 - 8.79). In contrast, low-lying wadi beds (e.g., Wadi Sharm El-Bahary beds) experience pronounced solute accumulation, with EC values soaring up to 9.50 ± 0.0286 dS/m and TDS reaching 6,031.89 ± 2.6191 mg/L. The coastal mangrove habitat at Wadi Sharm El-Bahary marks the extreme terminal sink of these drainage systems, where tidal intrusion and high evaporation create severe hyper salinity (EC = 25.68 ± 1.1994 dS/m, TDS = 14,277.37 ± 7.4993 mg/L) and massive concentrations of soluble ions like Mg^{++} (146.55 ± 6.8461 meq/L), Ca^{++} (96.68 ± 4.5165 meq/L), and HCO_3^{-} (103.42 ± 5.1239 meq/L) Appendix (3).

3.5. Hyperspectral analysis and application

3.5.1 Hyperspectral signature for plants

Fig. 7 illustrates the typical spectral signatures of 37 plant species that are found naturally in the study area. The results revealed a high degree of consistency in the spectral signatures across different plants, particularly in the visible and infrared regions of the spectrum.

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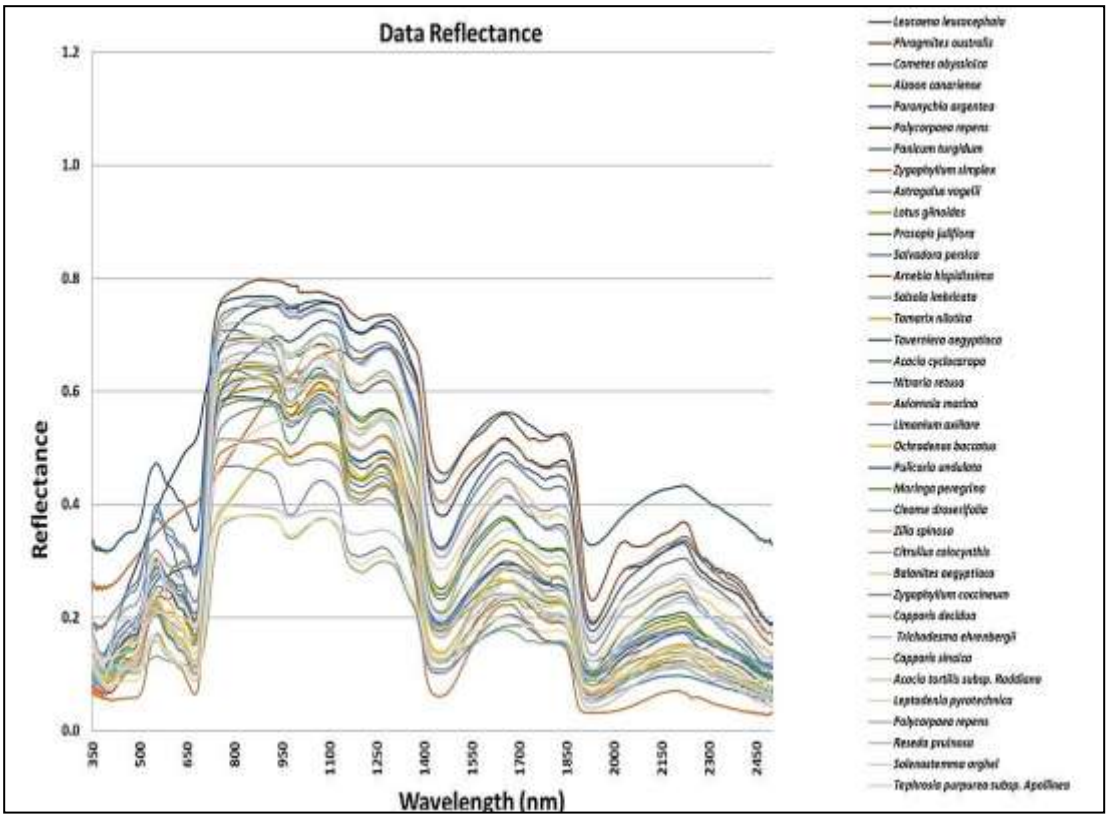


Fig. 7. The spectral reflectance pattern for the studied taxa

Among all spectral regions, *Phragmites australis*, *Leucaena leucocephala*, and *Paronychia argentea* showed higher reflectance compared to other species. *Avicennia marina* exhibited the lowest reflectance in the SWIR 1 and SWIR 2 zones (Fig.8). Additionally, *Leucaena leucocephala* and Salsola imbricata recorded higher reflectance values in the visible region than other species (Fig.8).

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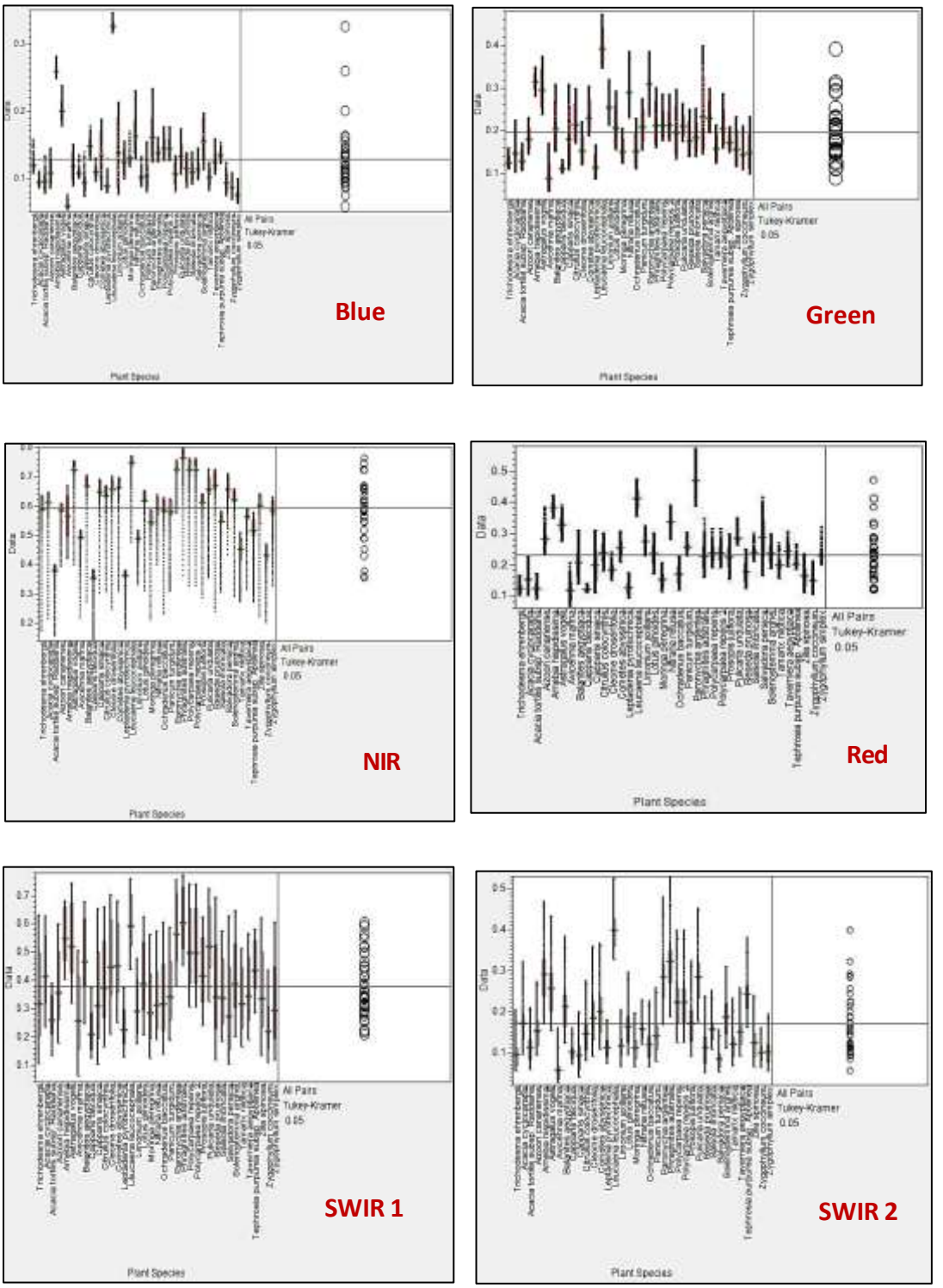


Fig. 8. ANOVA and Tukey's HSD analyses used to differentiate the studied taxa

3.5.2 Hyperspectral signature for soils

Fig. 9 illustrates the typical spectral signatures of soil samples from 22 different sites, showing variability across the visible (350-700 nm), near-infrared (NIR, 700-1400 nm), and shortwave-infrared (SWIR, 1400-2500 nm) regions (Fig. 10).

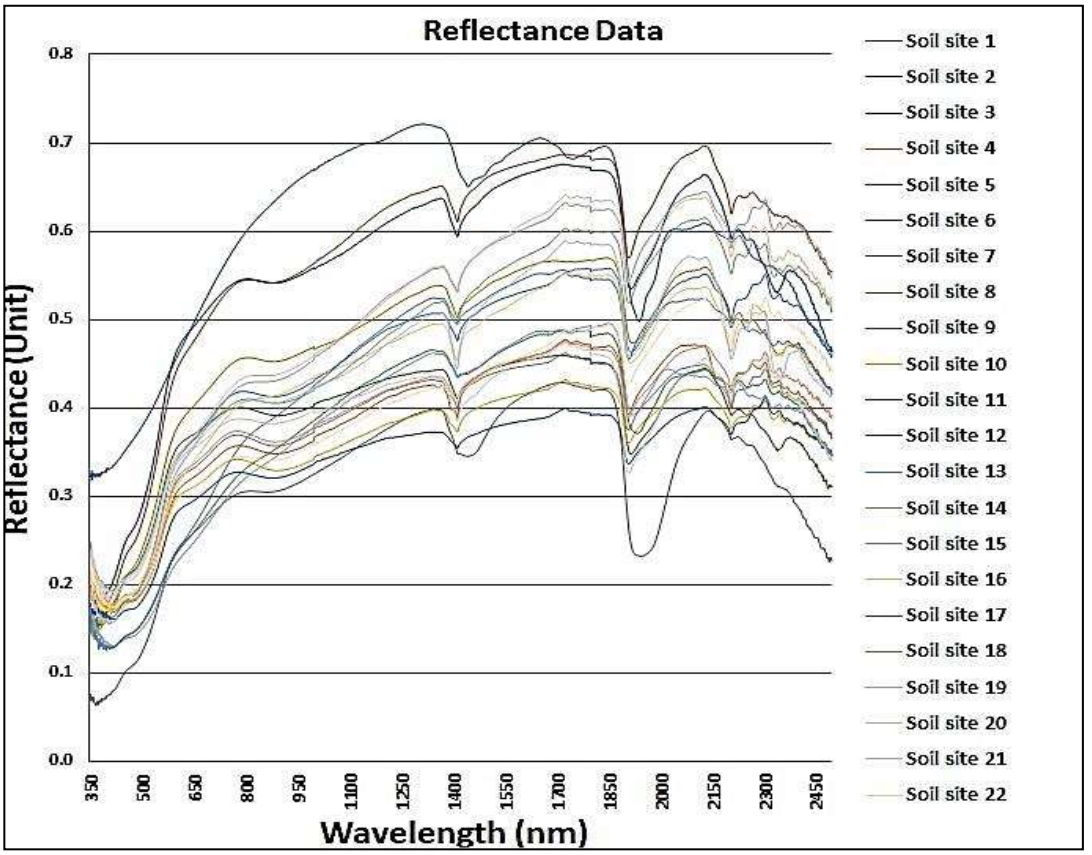


Fig. 9. Spectral reflectance patterns of the top soil in the examined soil profiles.

In the visible Region (350-700 nm), reflectance generally increases with wavelength. Soil sites 4, 5, and 7 show higher reflectance, indicating lower organic matter and higher mineral content, while in the Near-Infrared Region (700-1400 nm), High reflectance values suggest a high content of quartz and other silicate minerals. Soil sites 4, 5, and 11 exhibit higher reflectance, indicating robust mineral composition. In SWIR 1 & 2 (1400-2500 nm), multiple absorption features correspond to water and clay minerals (Fig. 10). Soil sites 7 and 16 show pronounced absorption, indicating higher clay and moisture content.

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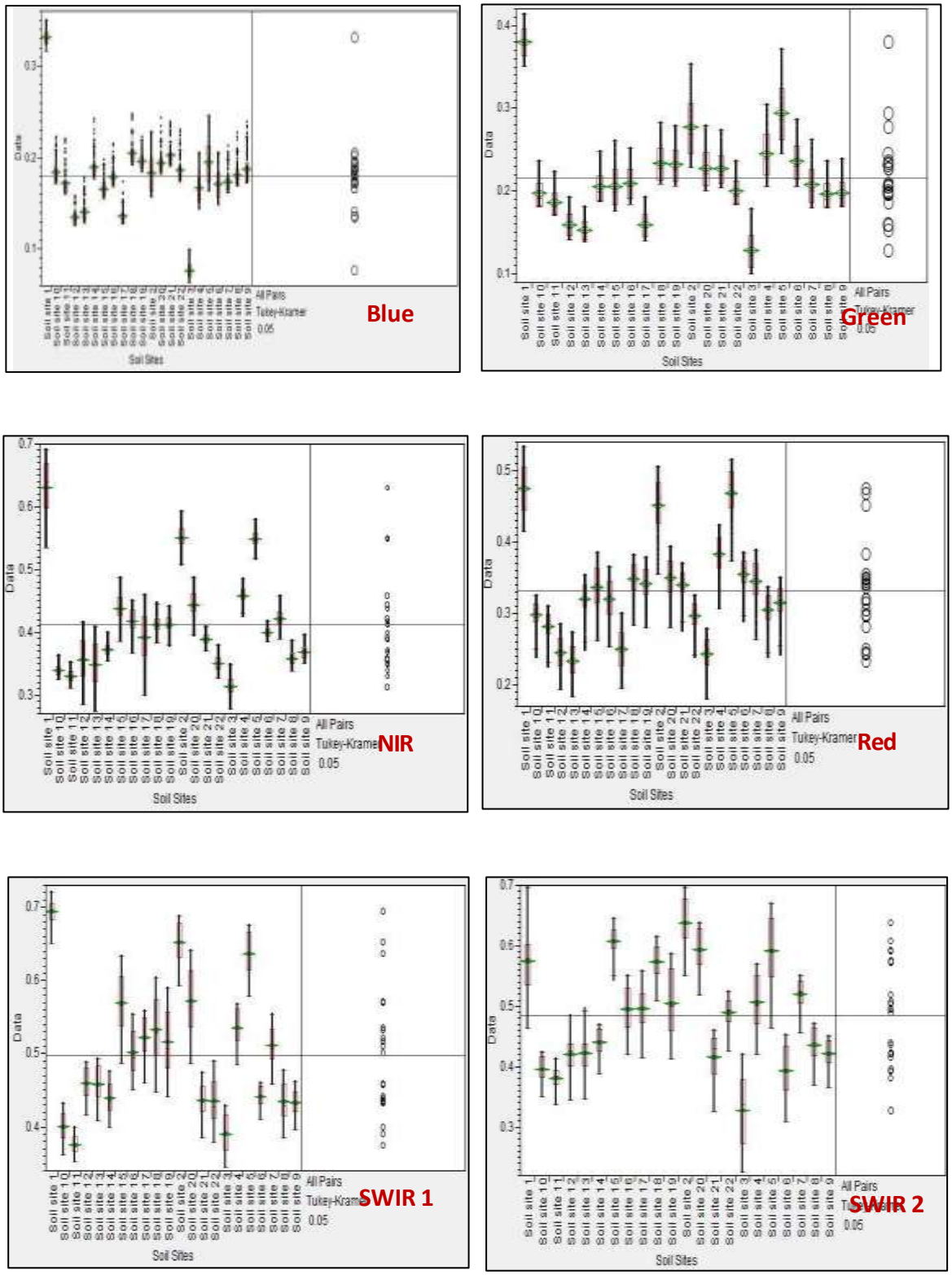


Fig.10. ANOVA and Tukey's HSD analysis of soil types across various spectral bands (Blue, Green, NIR, Red Zones, SWIRI, and SWIRI.

4. DISCUSSION

Floristic studies are not only important for exploring the floral diversity of an area, but are also of social and economic importance (Al-Mutairi *et al.* 2016). Floristic studies, despite being traditional, are crucial in modern botanical research as they help slow down human pressure on biodiversity, manage actions, and maintain conservation strategies (Wagensommer *et al.* 2023). The wild vegetation in the study area is composed of 42 perennials (70.00%) and 18 annuals species (30.00%) of the total recorded species. The current study's prevalence of perennials agrees with the findings of (Zahran & Willis. 2009; Abdelaal *et al.* 2016 and Bedair *et al.* 2021 on Wadi Hagul) and most recently (Salama *et al.* 2023) in the Eastern Desert of Egypt. The vegetation structure of some Wadis at the Red Sea coast is simple, requiring perennial species to endure harsh environmental conditions (Shawky and El-Khouly 2017). The desert harsh conditions pose a significant risk to the survival of plant species, particularly annuals (Hegazy *et al.*, 2008).

The study identifies three key families as leading taxa that constitute the major bulk flora of the study area were Fabacea (18.33%), Zygophyllaceae (11.67 %) and Asteraceae & (8.33 %), which contributed collectively about 38.33 % of the total recorded species. Comparable results have been reported in other studies (e.g., Abd El-Ghani et al., 2013; Kurd et al., 2017; El-Khouly and Shawky, 2017 and Salama *et al.*, 2018). Amro *et al.* (2021) demonstrated that the most prevalent flora in the North African and Mediterranean are Asteraceae, Zygophyllaceae, Fabaceae, Chenopodiaceae and Brassicaceae. Salama *et al.* (2023) reported that the four families Asteraceae, Poaceae, Fabaceae, and Zygophyllaceae make up the majority of the flora in the eastern desert of Egypt.

Asteraceae, Poaceae and Fabaceae represent the majority of Egyptian flora and adjacent countries such as Libya and Saudi Arabia (Täckholm 1974; Boulos 2009; El-Barasi *et al.*, 2011 and Ahmed *et al.* 2020). The highest among other perennial species were *Zilla spinosa* and *Zygophyllum coccineum* in the studied stands and spread their dominancy all over the Eastern Desert of Egypt (Shaltout *et al.* 2009; Abd El-Ghani *et al.* 2013a; Amro et al. 2021 and Salama *et al.* 2023).

According to El-Behairy et al. (2020) 41 alien species were not recorded in the last updated checklist of the Egyptian flora (Boulos, 2009). Among these invasive species is *Prosopis juliflora*, which spread clearly and has a negative impact on the biodiversity in the southeastern corner of Egypt (Mohamed *et al.*, 2015 and Slaltout *et al.*, 2016). It reduced plant diversity (Allelopathic effect), because it has massive impacts upon water resources (Weber, 2003), represent a tangible threat to the sustainability of existing natural resources in range and cultivated lands (Assaeed *et al.*, 2020; Badawy *et al.*, 2021 and Bedair, *et al.* 2021).

Kassas (1952) pointed out that Life form distribution of the desert plants is closely correlated with rainfall, topography and landform. The life form evolved as a result of climatic and environmental adaptation (Hegazy *et al.*, 2012 **and** Salama *et al.*, 2019). The present study demonstrated that different plant species were categorized to five life forms, Chamaephytes & therophytes (30.00 % each) and Phanerophytes (28.81%) constituted the largest number of species (53) with total value (88.33 %). While Hemicryptophytes (10.00%), Geophytes the lowest one (1.67%), are represented by only one species. Our results agreed with other reports (Abd El-Ghani et al., 2000 **&** 2013**;** Kurd *et al.*, 2017; Shawky and El-Khouly 2017 and Salama *et al.*, 2023) in the Eastern desert**.** According to (Hussien *et al.* 2019), chamaephytes were the most abundant life form, followed by therophytes, hemicryptophytes and phanerophytes in hyper-arid desert environments. From phanerophytes species, *Moringa*

peregrina was the most endangered tree where there is a sharp decline in its numbers and sizes of its populations in Egypt (Abd El-Wahab, 1995; Hegazy *et al*., 2007; Dadamouny, 2009 and Zaghloul *et al*., 2012).

Another aspect of floristic research is chorological affinity, which pertains to regional distributions and plant responses to environmental changes (Salama et al., 2023). Ecological adaptations of species affect how widely distributed a plant is (Zahran, 1982; Zahran and Willis 2009 and Hammad *et al*., 2024). For example, mangrove community occur in a zone following the shore-line, while other vegetation zones may include a mosaic of one or more than one community depending on local topography or soil conditions (Zahran and Willis, 2009).

The chorological analysis of the surveyed flora revealed that 29 species (48.33% of the total flora) were monoregional, of which 15 species (25.00%) were pure Saharo-Arabian chorotype. Saharo-Arabian species are abundant in the eastern desert in Egypt, this is may be attributed to their high tolerability to harsh desert environmental conditions (Amro *et al*., 2021 and Salama, 2023). 3 species (5.00%) included *Aizoon canariense*, and *Moringa peregrina* represented the typical (mono-regional) Sudano Zambezian chorotype, the same results reported by (Amro *et al*., 2021). The bioregional chorotype ranked second (36.67%), of which Saharo-Arabian, Sudano-Zambezian element have the highest share of the recorded species (21.67%). On the other hand, pluri-regional with low share (10.00%) and extending their distribution all over the Saharo-Arabian, Sudano- Zambezian, Irano-Turanian and Mediterranean regions. Our results coincide with others obtained by (Abutaha *et al*., 2019, 2020; Amro *et al*., 2021 and Salama *et al*., 2023) in Eastern desert in Egypt and (Ahmed *et al*., 2020) in Saudi Arabian.

Steep mountain slopes are dominated by residual, skeletal substrates rich in very coarse sand, this coarse composition is driven by gravitational wasting and the hydrological winnowing away of finer matrices on steep gradients (Bland & Rolls, 2016)**.** While the low-lying wadi beds characterized by finer deposits, which optimize localized water-holding capacity, creating more stable and favorable eco-hydrological niches that support richer floral communities and dense vegetation cover (Cody, 1989). On the other hand, mangrove habitat functioning as a low-energy tidally-influenced sediment sink, it sequesters the highest concentrations of fine material, specifically silt & clay, while retaining minimal coarse fragments due to the sudden loss of stream competence (Hogarth, 2015). These distinct textural variations illustrate how topography and surface hydrology interact to shape local edaphic conditions, directly dictating the spatial distribution and community structure of desert vegetation (Kassas, 1952). The steep, coarse-textured mountain slopes favor deeply anchored, resilient chasmophytes or specialized perennials capable of wedging into rocky crevices. Conversely, the finer, moisture-retentive alluvial soils of the wadis create a hospitable terrain for a wider diversity of ephemeral and woody species (Ayyad & El-Ghareeb, 1982), ultimately, this grain-size gradient establishes distinct micro-habitats across the desert landscape, demonstrating that mechanical sorting during transport and deposition is a primary driver of both soil development and ecological niche differentiation in hyper-arid ecosystems.

The spectral signatures of plant species provide insights into their ecological adaptations and health. For instance, species like *Phragmites australis* and *Leucaena leucocephala* show higher reflectance in various spectral regions, reflecting their robust physiological conditions and ability to thrive in diverse environments. Dominant life forms such as chamaephytes (low-

growing perennials) and therophytes (annuals) have distinct spectral characteristics linked to their photosynthetic activity and strategies for surviving harsh conditions. The study area predominantly features mono regional species, particularly Saharo-Arabian elements, adapted to arid environments. These species exhibit spectral signatures indicative of efficient water use and drought resistance. The spectral data reveal how different species manage water stress, with certain plants showing higher reflectance in the visible region due to chlorophyll content and others demonstrating lower reflectance in the infrared region due to water absorption. This connection between spectral signatures and ecological traits helps in understanding the health, stress levels, and adaptive strategies of the plant species in their natural habitats (Khdery 2019, 2020, 2021, 2023, Aboelghar and Gamal *et al*., 2020 and El-Shirbeny, 2021)**.**

The results demonstrate that soil texture, chemical composition, and moisture content are key factors affecting the spectral behavior of soil. Coarse-grained soils with low organic matter tend to have higher reflectance across the visible and NIR regions due to their mineral composition. In contrast, fine-grained soils with higher silt and clay content exhibit absorption features in the SWIR range, which are linked to water and clay minerals.Coarse sands found on the slopes of Gebel Umm Nakkat, Umm Lasifa, and El-Sibaie reflect more light in the visible spectrum due to lower organic content and larger particle size. Fine sands, particularly in Wadi Esel, scatter light and show moderate reflectance in the NIR region, where quartz and silicate minerals dominate. Mangrove habitats, with high silt and clay content (e.g., Wadi Sharm El-Bahary), show strong absorption in the SWIR range due to water and clay minerals.

Soils with a pH of 6.26–9.00, especially clay-rich soils, display absorption in the SWIR region, indicating moisture interaction. High electrical conductivity (EC) in mangrove and halophytic soils results in lower reflectance, while low-EC soils, such as Gebel El-Sibaie, exhibit higher reflectance in the NIR. Sites rich in quartz and silicates, like Gebel El-Sibaie, reflect strongly in the NIR range, while high mineral content (e.g., calcium and magnesium) in Wadi Sharm El-Bahary influences the spectral signature in the SWIR range through water and mineral absorption.

Conclusion

The present work is the first floristic study of Gebel El-Sebaie area, we found that vegetation within study area is restricted to a definite habitat depending on its ability to adapt to drought stress. Soil physical and chemical properties strongly influence their spectral signatures, supporting the use of remote sensing to differentiate soil types and environmental conditions. Our study is attempting to address the lack of and /or insufficient knowledge of plant diversity in less investigated regions, such as the Red Sea Mountains.

Author contributions

M.E. A., M. M. A., and N.M.H. carried out fieldwork, identification of species, and Conceptualization. Gh. A. Kh., M. M. A., and N. M. H. wrote original draft preparation, methodology, software, data curation, and formal analysis., M. M. A. and A. A. M. reviewed and edited the draft, while all authors contributed to the final version

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Data underlying the findings of this study will be made available from the corresponding author upon reasonable request.

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Appendix1: Species composition of the study area classified according to the different families, together with their chorology types, and the distribution of species in the studied Area. Gebel El-Sibaie (Se), Gebel Umm-Naqqat (Na), Gebel Umm-Lasifa (La), Wadi Sharm El-Bahari (Sh), Wadi Umm-Gheig (Gh), and Wadi Esel (Es). Life forms (Th: Therophytes, He: Hemicryptophytes, Ch: Chamaephytes, G: Geophytes and Ph: Phanerophytes).

No.	Family	Species incl. author	Life cycle	Life form	Grpwth form	Chorology	Study area					
							Se	Na	Gh	La	Sh	Es
1	Aizoaceae	*Aizoon canariense* L.	A	Th	herb	SU-ZA		*	*			
2	Amaranthaceae	*Aerva javanica* (Burm. f.) Juss. ex Schult. in Roem. & Schult. Var *javanica*	P	Ch	herb	SA-AR+SU-ZA		*				
3	Asclepiadaceae	*Leptadenia pyrotechnica* (Forssk.) Decne.	P	Ph	shrub	SA-AR+SU-ZA	*	*				*
4		*Solenostemma arghel* (Delile) Hayne	P	**Ch**	shrub	SA-AR	*	*	*			
5	Asteraceae	*Artemisia judaica* subsp. *Judaica* L., Mant. Alt.	P	**Ch**	shrub	SA-AR		*				
6		*Launaea capitata* (Spreng.) Dandy	A	Th	Herb	SA-AR			*			
7		*Pulicaria undulata* (L.) C.A.Mey.	P	Ch	shrub	SA-AR+SU-ZA		*				
8		*Pulicaria incisa* (Lam.) DC., Prodr.	P	Ch	herb	SA-AR+IR-TR	*					
9		*Senecio flavus* (Decne.) Sch. Bip.	A	Th	herb	SA-SI	*	*				
10	Avicenniaceae	*Avicennia marina* (Forssk.) Vierh.	P	**Ph**	tree	SA-AR					*	
11	Boraginaceae	*Arnebia hispidissima* (Sieber ex Lehm.) A.DC.	A	Th	herb	SA-AR+IR-TR	*		*			
12		*Trichodesma ehrenbergii* Schweinf.	P	H	herb	SU-ZA	*	*				
13	Brassicaceae	*Zilla spinosa* (L.) subsp. *spinosa*	P	**Ch**	shrub	SA-AR	*	*	*			*
14	Capparaceae	*Capparis decidua* (Forssk.) Edgew.	P	Ph	tree	SA-AR+SU	*		*			*
15		*Capparis sinaica Veill*	P	**Ch**	shrub	SA-SI	*	*	*	*		*
16	Caryophyllace	*Paronychia argentea* Lam.	A	Th	herb	ME			*			

	ae											
17		*Cometes abyssinica* R.Br. in Wall.	A	Th	herb	AF-MO		*	*			*
18		*Polycarpaea repens* (Forssk.) Asch. & Schweinf.	P	H	herb	SA-SI			*			
19		*Spergularia diandra* (Guss.) Boiss .	A	Th	herb	ME+SA-SI+IR-TR			*			
20	Chenopodiaceae	*Salsola imbricata Forssk.*	P	**Ch**	shrub	SA-AR			*		*	*
21	Cleomaceae	*Cleome amblyocarpa* Barratte & Murb.	A	Th	herb	SA-AR+SU-ZA			*			*
22		*Cleome chrysantha* Decne.	A	**Ch**	shrub	SA-SI	*					
23		*Cleome droserifolia* (Forssk.) Delile	P	**Ch**	shrub	SA-AR+IR-TR	*	*	*			*
24	Convolvulaceae	*Convolvulus hystrix* Vahl subsp. *hystrix*	P	Ch	shrub	SA-AR		*	*			*
25	Cucurbitaceae	*Citrullus colocynthis* (L.) Vahl .	P	H	herb	ME+SA-AR	*	*				
26	Fabaceae	*Acacia cyclocarpa* Maslin, M.D.Barrett & R.L.Barrett	P	Ph	tree	AUS						*
27		*Acacia ehrenbergiana Hayne.*	P	Ph	tree	SU						*
28		*Acacia tortilis* (Forssk.) Hayne subsp. raddiana (Savi) Brenan	P	Ph	tree	SA-AR+SU-ZA	*	*	*	*		*
29		*Acacia tortilis* (Forssk.) Hayne subspecies tortilis (Forssk.)	P	Ph	tree	SA-AR+SU-ZA	*	*	*			*
30		*Astragalus eremophilus* Boiss.	A	Th	herb	SA-AR			*			
31		*Astragalus vogelii* (Webb) Bornm.	A	Th	herb	SA-AR			*			
32		*Leucaena leucocephala* (Lam.) de Wit	P	Ph	shrub	AM						*
33		*Lotus glinoides* Delile	A	Th	herb	SA-SI			*			
34		*Prosopis juliflora*	P	Ph	shrub	AM						*
35		*Taverniera aegyptiaca* Boiss.	P	Ch	shrub	SA-AR			*		*	*

36		*Tephrosia purpurea* (L.) Pers. subsp. *apollinea* (De lile) Hosni & El-Karemy	P	Ch	herb	SA-AR	*	*				
37	Liliaceae	*Asphodelus tenuifolius* Cav.	A	Th	herb	ME+SA-AR+IR-TR		*				
38	Malvaceae	*Malva parviflora* L.	A	Th	herb	ME+IR-TR+ER-SR						*
39	Moringaceae	*Moringa peregrina* (Forssk.) Fiori	P	Ph	tree	SU-ZA	*	*		*		
40	Nitrariaceae	*Nitraria retusa* (Forssk.) Asch.	P	Ph	shrub	SA-AR+SU-ZA		*	*			*
41	Plumbaginaceae	*Limonium axillare* (Forssk.) Kuntze	P	Ch	shrub	SA-AR+SU-ZA					*	
42	Poaceae	*Aristida funiculata* Trin. & Rupr.	A	Th	grass	SA-AR			*			
43		*Panicum turgidum* Forssk.	P	G	grass	SA-AR+IR-TR		*	*			
44		*Phragmites australis* (Cav.) Trin. ex Steud.	P	G	shrub	Pan					*	
45	Resedaceae	*Ochradenus baccatus* Delile	P	Ph	shrub	SA-AR+SU-ZA	*	*	*			*
46		*Reseda pruinosa* Delile	A	Th	herb	SA-AR	*	*	*			
47	Rhamnaceae	*Ziziphus spina-christi* (L.) Desf.	P	Ph	tree	SA-AR+SU-ZA	*					
48	Rubiaceae	*Crucianella membranacea* Boiss.	A	Th	herb	SA-AR						*
49	Salvadoraceae	*Salvadora persica* L.	P	Ph	shrub	SA-AR+SU-ZA		*	*			
50	Scrophulariaceae	*Kickxia acerbiana* (Boiss.) Tackh. & Boulos.	P	He	herb	SA-SI	*					
51	Solanaceae	*Lycium shawii* Roem. & Schult.	P	Ph	shrub	SA-AR+SU-ZA+IR-TR	*	*	*			*
52	Tamaricaceae	*Tamarix nilotica* (Ehrenb.) Bunge	P	Ph	tree	SA-AR+IR-					*	*

						TR						
53	Urticaceae	*Forsskaolea tenacissima* L.	P	H	herb	SA-AR+SU-ZA	*					
54	Zygophyllaceae	*Balanites aegyptiaca* (L.) Delile	P	Ph	tree	SA-AR+SU-ZA	*	*	*			*
55		*Fagonia arabica* L. var. *arabica*	P	**Ch**	herb	SA-AR+IR-TR	*	*				
56		*Fagonia mollis* Delile	P	**Ch**	shrub	SA-AR+IR-TR	*	*	*			
57		*Tribulus terrestris* L.	A	Th	herb	Pan		*				*
58		*Zygophyllum album* L.f.	P	**Ch**	herb	ME+SA-AR+IR-TR			*		*	*
59		*Zygophyllum coccineum* L.	P	**Ch**	shrub	ME+SA-AR+SU-ZA	*		*		*	*
60		*Zygophyllum simplex* L.	A	Th	herb	SA-AR	*		*			

Appendix (2). Means and standard deviations for soil physical properties of the twenty-four sites at depth (0-20cm) in the study area. ANOVA test is for original where values are normally distributed. F-value refer to the ANOVA. Small letters denote the statistically different sites as identified by ANOVA.

Sites	Habitat	Particle size distribution (%)					
		Very coarse sand	Coarse sand	Medium sand	Fine sand	Very fine Sand	Silt & Clay
El-Sebaie mountain	Slope	^{d} 46.23 ± 3.0820	^{hij} 18.15 ± 2.0167	^{f} 14.03 ± 1.5589	^{h} 9.08 ± 1.0089	^{gh} 6.48 ± 0.7200	^{gh} 6.03 ± 0.6700
		^{JK} 19.36 ± 1.2907	^{gh} 21.64 ± 2.4044	^{e} 17.64 ± 1.9600	^{e} 12.76 ± 1.4178	^{ef} 16.38 ± 1.8200	^{d} 12.22 ± 1.3578
		^{hi} 26.57 ± 1.7713	^{a} 47.49 ± 5.2767	^{de} 20.06 ± 2.2289	^{I} 3.62 ± 0.4022	^{i} 1.53 ± 0.1700	^{jk} 0.73 ± 0.0811
		^{b} 59.63 ± 3.9753	^{de} 29.56 ± 3.2844	^{hi} 8.85 ± 0.9833	^{ijk} 1.25 ± 0.1389	^{I} 0.44 ± 0.0489	^{k} 0.27 ± 0.0300
		^{ef} 37.89 ± 2.5260	^{ijk} 15.92 ± 1.7689	^{a} 27.64 ± 3.0711	^{h} 7.67 ± 0.8522	^{gh} 6.00 ± 0.6667	^{hi} 4.88 ± 0.5422
		^{b} 61.03 ±	^{cde} 30.84 ±	^{I} 6.64 ±	^{jk} 0.84 ±	^{I} 0.35 ±	^{k} 0.30 ±

		4.0687	3.4267	0.7378	0.0933	0.0389	0.0333
	Wadi bed	^{o} 2.62 ± 0.1747	^{l} 3.79 ± 0.4211	^{I} 6.18 ± 0.6867	^{d} 15.97 ± 1.7744	^{b} 38.58 ± 4.2867	^{c} 32.86 ± 3.6511
		^{c} 53.32 ± 3.5547	^{bc} 36.04 ± 4.0044	^{I} 6.80 ± 0.7556	^{ijk} 1.46 ± 0.1622	^{I} 1.95 ± 0.2167	^{k} 0.43 ± 0.0478
		^{mn} 10.00 ± 0.6667	^{k} 10.58 ± 1.1756	^{e} 17.34 ± 1.9267	^{c} 20.02 ± 2.2244	^{c} 32.03 ± 3.5589	^{def} 10.03 ± 1.1144
		^{fg} 33.52 ± 2.2347	^{b} 39.23 ± 4.3589	^{cde} 20.29 ± 2.2544	^{ij} 3.22 ± 0.3578	^{I} 2.04 ± 0.2267	^{jk} 1.70 ± 0.1889
		^{hi} 26.64 ± 1.7760	^{fgh} 22.13 ± 2.4589	^{gh} 10.82 ± 1.2022	^{fgh} 10.10 ± 1.1222	^{ef} 19.30 ± 2.1444	^{de} 11.01 ± 1.2233
Wadi Esel	Wadi bed	^{o} 1.45 ± 0.1611	^{l} 1.63 ± 0.1811	^{j} 1.67 ± 0.1856	^{efg11}.71 ± 1.3011	^{a} 45.85 ± 5.0944	^{b} 37.69 ± 4.1878
		^{n} 7.63 ± 5.8692	^{jk} 14.71 ± 1.6344	^{ab} 25.84 ± 2.8711	^{a} 24.43 ± 2.7144	^{e} 19.75 ± 2.1944	^{fg} 7.64 ± 0.8489
Umm Lasifa mountaion	Slope	^{b} 64.39 ± 4.2927	^{efg} 26.31 ± 2.9233	^{I} 6.06 ± 0.6733	^{ijk} 1.55 ± 0.1722	^{I} 0.38 ± 0.0422	^{jk} 1.31 ± 0.1456
Wadi Sharm El-Bahary	Mangrove	^{o} 2.77 ± 0.1847	^{k} 10.48 ± 1.2200	^{hi} 7.83 ± 0.8700	^{ef} 11.93 ± 1.3256	^{d} 25.05 ± 2.7833	^{a} 41.44 ± 4.6044
	Wadi bed	^{lmn} 12.06 ± 0.8040	^{hij} 17.18 ± 1.9089	^{bcd} 22.72 ± 2.5244	^{bc} 21.51 ± 2.3900	^{rf} 17.82 ± 1.9800	^{efg} 8.71 ± 0.9678
Umm Naqqat mountain	Slope	^{de} 42.28 ± 2.8187	^{bc} 36.08 ± 4.0089	^{fg} 12.11 ± 1.3456	^{I} 3.63 ± 0.4033	^{hi} 3.46 ± 0.3844	^{ijk} 2.44 ± 0.2711
		^{a} 75.75 ± 5.0500	^{hi} 20.34 ± 2.2600	^{j} 2.54 ± 0.2822	^{k} 0.39 ± 0.0433	^{I} 0.47 ± 0.0522	^{jk} 0.51 ± 0.0567
		^{ij} 23.5 ± 1.5667	^{def} 27.13 ± 3.0144	^{b} 24.11 ± 2.6789	^{ef} 12.52 ± 1.3911	^{g} 9.26 ± 1.0289	^{hij} 3.48 ± 0.3867
	Wadi bed	^{de} 42.12 ± 2.8080	^{a} 48.85 ± 5.4279	^{hi} 8.51 ± 0.9454	^{k} 0.43 ± 0.0478	^{I} 0.05 ± 0.0056	^{k} 0.04 ± 0.0044
		^{d} 47.04 ± 3.1360	^{cde} 31.48 ± 3.4978	^{f} 14.21 ± 1.5789	^{ij} 3.27 ± 0.3633	^{I} 2.31 ± 0.2567	^{jk} 1.69 ± 0.1878
Wadi Umm Gheig	Wadi bed	^{gh} 29.22 ± 1.9480	^{cd} 32.02 ± 3.5578	^{b} 24.22 ± 2.6911	^{gh} 9.40 ± 1.0444	^{hi} 3.12 ± 0.3467	^{jk} 2.02 ± 0.2244

		[kl] 14.96 ± 0.9973	[jk] 13.33 ± 1.4811	[bc] 23.43 ± 2.6033	[ab] 22.99 ± 2.5544	[f] 16.18 ± 1.7978	[ef] 9.11 ± 1.0122
		[lm] 12.96 ± 0.8640	[hij] 17.69 ± 1.9656	[bc] 23.51 ± 2.6122	[bc] 21.88 ± 2.4311	[f] 16.12 ± 1.7911	[fg] 7.84 ± 0.8711
F- value		180.1803	52.483	56.792	100.686	136.348	164.561
$LSD_{0,05}$		4.582	4.891	3.046	2.267	3.185	14.997

Appendix (3). Means and standard deviations for soil chemical properties of the twenty-four sites at depth (0-20cm) in the study area. ANOVA test is for original where values are normally distributed. F-value refer to the ANOVA. Small letters denote the statistically different sites as identified by ANOVA

location	Habitat	EC ds/m	PH	TDS Mg / L	Soluble cations (meq / L)				Soluble anions (meq / L)			P mg /L
					Ca^{++}	Mg^{++}	Na^{+}	K^{+}	$HCO3^{-}$	SO_4^{-2}	Cl^{-}	
El-Sebaie mountain	Slope	[ij] 0.28 ± 0.0075	[b] 8.79 ± 0.0068	r 175.61 ± 0.3856	[g] 1.53 ± 0.0411	[g] 0.20 ± 0.0055	[mno] 0.64 ± 0.0172	[jk] 0.43 ± 0.0115	[fg] 1.23 ± 0.0433	[l] 1.02 ± 0.0358	[j] 0.58 ± 0.0204	[gh] 18.09 ± 0.3547
		[hi] 0.71 ± 0.0231	[k] 8.00 ± 0.0033	n 430.66 ± 0.4929	[f] 4.89 ± 0.1580	[g] 0.82 ± 0.0264	[lm] 0.94 ± 0.0303	[hi] 0.50 ± 0.0162	[efg] 2.59 ± 0.1180	[l] 2.13 ± 0.0971	[h] 2.54 ± 0.1157	[o] 5.599 ± 0.1098
		[j] 0.22 ± 0.0182	[e] 8.50 ± 0.0045	[w] 125.67 ± 0.3627	[g] 0.79 ± 0.0662	[g] 0.30 ± 0.0249	[lmn] 0.91 ± 0.0765	[mn] 0.17 ± 0.0143	[fg] 1.22 ± 0.0731	[l] 0.40 ± 0.0241	[j] 0.49 ± 0.0292	[jk] 14.19 ± 0.2782
		[j] 0.23 ± 0.0056	[h] 8.20 ± 0.0034	[v] 129.90 ± 0.4567	[g] 1.02 ± 0.0253	[g] 0.54 ± 0.0134	[o] 0.51 ± 0.0127	[mn] 0.18 ± 0.0043	[fg] 1.23 ± 0.0520	[l] 0.47 ± 0.0197	[j] 0.61 ± 0.0256	[k] 13.67 ± 0.2680
		[ij] 0.35 ± 0.0036	[e] 8.50 ± 0.0031	[p] 224.43 ± 0.3286	[g] 2.10 ± 0.0211	[g] 0.11 ± 0.0011	[lmno] 0.88 ± 0.0088	[ij] 0.46 ± 0.0047	[g] 1.12 ± 0.0021	[l] 1.75 ± 0.0033	[j] 0.71 ± 0.0014	[j] 14.55 ± 0.2853
		[ij] 0.36 ± 0.0023	[n] 7.50 ± 0.0049	[q] 215.90 ± 0.7962	[g] 1.99 ± 0.0127	[g] 0.42 ± 0.0027	[kl] 1.05 ± 0.0067	[mn] 0.18 ± 0.0011	[fg] 1.40 ± 0.0063	[l] 1.33 ± 0.0060	[ij] 0.95 ± 0.0043	[r] 0.0049 ± 0.0001
	Wadi bed	[g] 1.41 ± 0.0608	[j] 8.10 ± 0.0029	[j] 846.09 ± 0.9253	[f] 6.55 ± 0.2831	[g] 1.31 ± 0.0567	[i] 4.12 ± 0.1779	[b] 2.09 ± 0.0904	[def] 3.31 ± 0.2000	[hi] 7.96 ± 0.4808	[h] 2.67 ± 0.1615	[e] 22.26 ± 0.4365
		[gh] 1.07 ± 0.0046	[n] 7.49 ± 0.0052	[l] 661.92 ± 0.4072	[f] 5.80 ± 0.0248	[g] 1.24 ± 0.0053	[j] 1.95 ± 0.0083	[c] 1.68 ± 0.0072	[de] 3.77 ± 0.0211	[k] 4.56 ± 0.0256	[h] 2.36 ± 0.0132	[c] 30.06 ± 0.5894
		[e] 3.64 ± 0.0424	[s] 6.89 ± 0.0048	[f] 2130.88 ± 0.8898	[d] 18.56 ± 0.2162	[e] 11.35 ± 0.1323	[g] 6.05 ± 0.0704	[jk] 0.43 ± 0.0050	[b] 15.15 ± 0.4277	[f] 15.55 ± 0.4389	[f] 6.41 ± 0.1809	[a] 40.25 ± 0.7892
		[g] 1.38 ± 0.0437	[m] 7.79 ± 0.0164	[I] 868.44 ± 0.6732	[f] 5.86 ± 0.1853	[fg] 2.17 ± 0.0686	[h] 4.87 ± 0.1541	[d] 0.91 ± 0.0288	[efg] 2.67 ± 0.0115	[hij] 7.30 ± 0.0316	[g] 4.28 ± 0.0185	[f] 21.21 ± 0.4159
		[gh] 1.01 ± 0.0113	[p] 7.19 ± 0.0050	[m] 632.12 ± 0.2536	[f] 5.47 ± 0.612	[fg] 1.98 ± 0.0222	[j] 2.16 ± 0.0242	[h] 0.51 ± 0.0057	[efg] 2.36 ± 0.0360	[jk] 5.93 ± 0.0906	[hi] 1.88 ± 0.0287	[k] 13.67 ± 0.2680

Wadi Esel	Wadi bed	[d] 5.86 ± 0.0559	[u] 6.49 ± 0.0237	[e] 3580.61 ± 1.2263	[c] 25.81 ± 0.2463	[e] 10.33 ± 0.0986	[b] 20.76 ± 0.1981	[c] 1.65 ± 0.0157	[c] 7.66 ± 0.0741	[e] 26.75 ± 0.2589	[b] 24.15 ± 0.2336	[q] 0.6539 ± 0.0128
		[g] 1.32 ± 0.0117	[l] 7.90 ± 0.0004	[k] 823.56 ± 0.2626	[f] 5.99 ± 0.0532	[fg] 1.86 ± 0.0165	[h] 4.97 ± 0.0442	[l] 0.38 ± 0.0034	[fg] 1.67 ± 0.0157	[ij] 6.89 ± 0.0648	[g] 4.65 ± 0.0438	[r] 0.0047 ± 0.0009
Umm Lasifa mountaion	Slope	[ij] 0.24 ± 0.0169	[d] 8.60 ± 0.0153	[u] 135.96 ± 0.4434	[g] 0.59 ± 0.0417	[g] 1.11 ± 0.0786	[no] 0.54 ± 0.0383	[n] 0.147 ± 0.0104	[fg] 1.34 ± 0.1067	[l] 0.58 ± 0.0459	[j] 0.51 ± 0.0406	[n] 6.64 ± 0.1302
Wadi Sharm El-Bahary	Mangrove	[a] 25.68 ± 1.1994	[a] 9.00 ± 0.0015	[a] 14277.37 ± 7.4993	[a] 96.68 ± 4.5165	[a] 146.55 ± 6.8461	[d] 12.70 ± 0.5934	[e] 0.82 ± 0.0383	[a] 103.42 ± 5.1239	[a] 96.65 ± 4.7884	[a] 57.57 ± 2.8525	[g] 18.55 ± 0.3637
	Wadi bed	[b] 9.50 ± 0.0286	[r] 7.05 ± 0.0407	[b] 6031.89 ± 2.6191	[b] 37.30 ± 0.1124	[c] 33.20 ± 0.1000	[a] 23.87 ± 0.0719	f 0.66 ± 0.0020	[c] 8.61 ± 0.1198	[b] 71.19 ± 0.9906	[d] 16.45 ± 0.2289	[b] 34.23 ± 0.6712
Umm Naqqat moutain	Slope	[ij] 0.40 ± 0.0110	[I] 8.16 ± 0.0397	[o] 251.00 ± 0.2569	[g] 1.98 ± 0.0544	[g] 0.29 ± 0.0081	[k] 1.35 ± 0.0370	[kl] 0.40 ± 0.0108	[fg] 1.26 ± 0.0035	[l] 2.10 ± 0.0059	[j] 0.71 ± 0.0020	[m] 7.421 ± 0.1455
		[ij] 0.28 ± 0.0036	[c] 8.65 ± 0.0503	[s] 168.60 ± 0.3090	[g] 1.44 ± 0.0185	[g] 0.60 ± 0.0077	[mno] 0.56 ± 0.0072	[mn] 0.18 ± 0.0023	[g] 1.10 ± 0.0415	[l] 1.07 ± 0.0407	[j] 0.70 ± 0.0263	[d] 26.16 ± 0.5129
		[f] 3.07 ± 0.1270	[v] 6.26 ± 0.0524	[g] 1773.17 ± 1.7242	[e] 14.10 ± 0.5836	[e] 10.09 ± 0.4177	[g] 5.95 ± 0.24.61	[g] 0.55 ± 0.0227	[b] 14.60 ± 0.9003	[h] 8.86 ± 0.5463	[e] 8.01 ± 0.4938	[h] 17.831 ± 0.3496
	Wadi bed	[ij] 0.26 ± 0.0073	[g] 8.40 ± 0.0029	[t] 149.67 ± 0.5997	[g] 0.91 ± 0.0257	[g] 0.81 ± 0.0229	[lmno] 0.68 ± 0.0193	[m] 0.20 ± 0.0057	[fg] 1.23 ± 0.0442	[l] 0.64 ± 0.0229	[j] 0.75 ± 0.0270	[p] 3.777 ± 0.0741
		[ij] 0.25 ± 0.0096	[f] 8.45 ± 0.0457	[t] 148.36 ± 0.8476	[g] 1.30 ± 0.0493	[g] 0.22 ± 0.0082	[lmno] 0.82 ± 0.0310	[mn] 0.19 ± 0.0071	[g] 1.00 ± 0.0163	[l] 0.95 ± 0.0156	j 0.60 ± 0.0099	[l] 11.32 ± 0.2220
Wadi Umm Gheig	Wadi bed	[f] 2.96 ± 0.0665	[t] 6.70 ± 0.0030	[h] 1758.54 ± 1.1691	[d] 18.11 ± 0.4063	[f] 4.27 ± 0.0957	[f] 6.70 ± 0.1502	[g] 0.55 ± 0.0123	[fg] 1.57 ± 0.0241	[g] 12.50 ± 0.1922	[d] 15.68 ± 0.2410	[i] 16.27 ± 0.3190
		[c] 6.29 ± 0.0084	[q] 7.09 ± 0.0046	[d] 3907.94 ± 0.7534	[c] 25.12 ± 0.0335	[d] 22.90 ± 0.0305	[e] 8.71 ± 0.0116	[a] 6.13 ± 0.082	[d] 5.04 ± 0.0015	[d] 38.30 ± 0.0114	[c] 19.55 ± 0.0058	[o] 5.662 ± 0.1110
		[c] 6.69 ± 0.2562	[o] 7.27 ± 0.0285	[c] 4125.10 ± 3.7201	[e] 13.71 ± 0.5253	[b] 35.98 ± 1.3788	[c] 17.02 ± 0.6520	[n] 0.15 ± 0.0057	[d] 4.93 ± 0.1917	[c] 45.76 ± 1.7797	[d] 16.22 ± 0.6307	[l] 11.42 ± 0.2239
F- value		1391.7455	3434.9918	7785170.8	1403.9216	1360.5412	3310.3176	8918.7742	1130.438	1566.7158	1298.4577	2708.515
$LSD_{0,05}$		0.416	0.038	3.155	1.553	2.346	0.332	0.038	1.754	1.771	1.007	0.580

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