Studia Universitatis "Vasile Goldiş", Seria Ştiinţele Vieţii
Vol. 36, issue 3, 2026, pp. 127 - 140

FLORISTIC INVENTORY AND CONSERVATION STATUS OF WILD PLANT SPECIES IN THE PETRIFIED FOREST PROTECTED AREA, CAIRO, EGYPT

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Abstract: The principal aim of the present study is to enrich our knowledge of the floral diversity in the Petrified Forest Protected Area in Cairo and identify the pressures of human activities that threaten the conservation of vegetation cover. Based on field surveys that were carried out from 2018 to 2023, 45 wild plant species representing 25 families were recorded and identified in the area. The area exists only as a paper park, lacks effective management capacity and is unlikely to achieve successful conservation in its current status. The objective of the proposed plan is to protect the natural vegetation cover along with its underlying ecological structure and supporting ecosystem processes, and promote environmental education.

Keywords: protected areas, wild flora, Petrified Forest, Cairo, biodiversity, plant conservation.

INTRODUCTION

The Kunming–Montreal Global Biodiversity Framework calls for rapid global expansion of protected areas in response to ongoing ecosystem degradation and biodiversity loss (CBD, 2022). One of its strongest selling points is the benefits protected areas provide to adjacent human communities (Cumming, 2025a). These spillover effects span social, ecological and economic spheres, and may include such critical benefits as water provisioning, pest control, pollination, flood and storm protection, forest regeneration, increased amenity and land prices (Cumming et al., 2025b).

Under current global trends of loss and degradation of natural habitats, protected areas are critical for conserving biodiversity and maintaining the ecosystem goods and services that human societies depend on (Zeng et al., 2022; Brodie et al., 2023). Moreover, climate change as well as increasing human pressures, such as overgrazing and habitat fragmentation, threatens this biodiversity hotspot, necessitating urgent conservation strategies and plans informed by ecological studies (El-Khalafy et al., 2024; Moustafa et al., 2024).

The establishment of protected areas (PAs) and the restriction of anthropogenic activities within PAs are considered to be the most successful and globally implemented measures to conserve endangered ecosystems (Geldmann et al., 2013; Nelson and Chomitz, 2011; Le Saout et al., 2013). anthropogenic habitat loss and disturbance have been identified as the key drivers of the biodiversity crisis occurring at the edge of Pas (Wittemyer et al., 2008; Ellis, 2011; Hansen and DeFries, 2007). Many terrestrial PAs have rapidly become isolated and shrunk due to logging, overgrazing, and land development (Wittemyer et al., 2008; DeFries et al., 2007; Liu et al., 2001; Fischer and Lindenmayer, 2007), raising questions about whether PAs have been effectively implemented. Globally, anthropogenic activities have directly disturbed the structure and composition of ecosystems (McIntyre and Hobbs, 1999), and the natural disturbance of vegetation patterns (Betts et al., 2017). Regarding terrestrial PAs, the native vegetation cover is a vital component providing habitat and forage to sustain wildlife populations (Stuart Chapin et al., 2012). Moreover, PA management approaches have the potential to affect the health status of ecosystems and landscape structures which leads to subsequent disturbances (Geldmann et al., 2013), and the estimated future decline in vegetation due to climate change (Allen et al., 2010),

The Protected Areas (PAs) have long been regarded as an important tool for conserving habitat integrity and species diversity (Brooks et al., 2004), the protected areas covering more than 12.7% of the land surface worldwide (Bertzky et al., 2012). Nowadays protected areas are the main tool for conserving biodiversity and ecosystems (SERI and IUCN, 2004) Moreover, there is considerable debate on the extent to which PAs deliver conservation outcomes in terms of habitat and species conservation (Brooks et al., 2006). It has been suggested that many of the world's PAs exist only as 'paper parks' (Dudley and Stolton, 1999), lacking effective management capacity, and unlikely to deliver effective conservation (Joppa et al., 2008). The protected areas (PAs) are often treated as a single conservation strategy. However, in reality they are established for a variety of reasons, with very different objectives and criteria for success. PAs have been set up for the conservation of ecosystems and their constituent species (Dudley, 2008), conservation of specific threatened species (Liu et al., 2001), or for cultural and social reasons (Coad et al., 2008). Understanding the conditions under which PAs deliver conservation benefits for species and habitats is essential for policy makers, managers and conservation advocates (Brooks et al., 2004).

Protected areas may also impose costs on adjacent human populations—for example, by increasing human–wildlife conflict (Sabuhoro et al., 2023), providing reservoirs for pathogens (Eby et al., 2023) and restricting access to resources (Cumming et al., 2023)

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In Egypt, the desert vegetation is by far the most the flora of Egypt is well documented in many referral books such as Täckholm (1974); Boulos (1995; 1999; 2000; 2002; 2005). It comprises some 2121 species and 153 infraspecific epithets (subspecies, variety, forma) of native and naturalized vascular plants (Boulos, 1995); in addition to 158 species of mosses and hepatics (El-Saadawi and Shabbara, 2007). Important and characteristic type of natural plant life. It covers about 95% of the total area of Egypt, and is mainly formed of xerophytic shrubs and sub-shrubs. Monod (1954) recognized two types of desert vegetation, namely contracted and diffuse. Both types refer to permanent vegetation that can be accompanied by ephemeral (or annual) plant growth depending on the amount of precipitation in a given year. Moreover, the flora of the Western Desert has been a subject of study by numerous authors either in the context of the entire flora of the country (Tackholm, 1974). The present-day plant life in the Western Desert is poor both in diversity and plant cover (Boulos, 1975).

The principal objective of the present study is to enhance our understanding of floral diversity in the Cairo Petrified Forest Protected Area, to identify the threats facing its vegetation cover, and to examine differing attitudes toward underlying causes and recommended solutions. Ultimately, these efforts aim to assist scientists and decision-makers in achieving effective management of the area.

MATERIALS AND METHODS

The study area

The Eastern Desert of Egypt occupies the area extending from the Nile Valley eastward to the Gulf of Suez and the Red Sea which is about 223,000 km², i.e. 21% of the total area of Egypt (Zahran, 2010). It is higher than the Western Desert as it consists essentially of a backbone of high, rugged mountains running parallel to and at a relatively short distance from the coast. The peaks of many of these mountains are more than 1500 m above sea level (Abu Al-Izz, 1971).

Sallam and Ruban (2017) reported that, the Maadi Petrified Forest is a palaeogeographic geosite of global rank as geosites of such geo-heritage value are rare on the planetary scale. The area contains fossilized stumps and logs, mainly of legume trees (Hassan, 2015). Futhermore, the area occupied by the Petrified Forest Protected Area that located at east of Cairo governorate (at Qattamiya, near Ma'adi in the north of Eastern Desert of Egypt), which is an extension of the eastern side of Gebel Mokattam, was intensively studied over the last one and a half centuries by many geologists starting with Rüssegger (1836), Linant de B. (1840) and many others, and referred to by El-Saadawi (1979). More recently, the stratigraply of the area was discussed in great detail by Strougo (1985, 1988) and Gingerich (1992). This so-called Petrified Forest covers a large area (over 300 km2) extending for tens of kilometers from Qattamiya towards Suez in the east (Zahran and Willis, 2009).

The area includes a large number of silicified massive tree trunks lying horizontally on the surface or buried partly or completely by sand or basalt, inside and outside the Cairo Petrified Forest Protected Area. The trunks inside the protected area are of late Eocene age and occur in the Ma'adi Formation while those overlain by basalt and occurring (Figure 1).

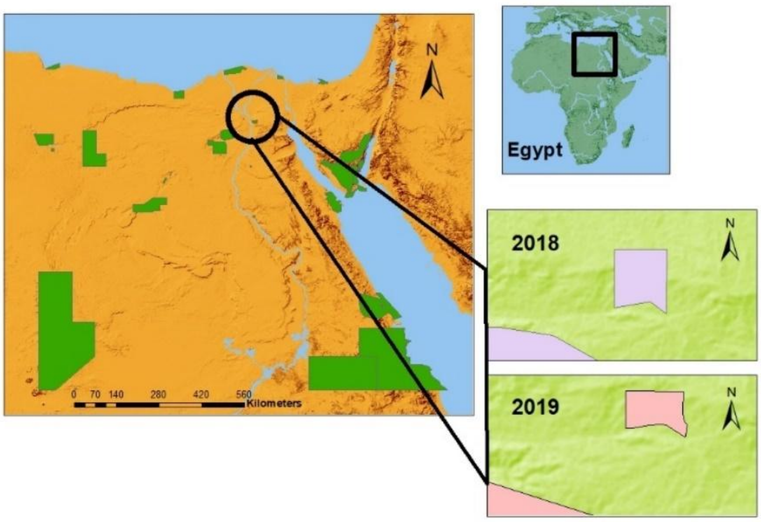


Fig. 1. Map of Egypt and locations of the current protected areas network and location the Petrified Forest Protectorate (left) and focusing on the boundaries modified and area changes (right) in year 2018 (7 km²) and after 2019 (3.3km²).

Moreover, the only authentic Petrified Forest area would be that area of about 7 km² as has been declared as a Natural Reserve by decree 944/1989 represents an exquisite scientific, touristic and cultural site. The boundaries of the Petrified Forest Protected Area were modified curentaly to 3.3 km², according to the amendment made by the Ministry of Environment in recent years.

The Eastern-Desert encompasses a semiarid/arid/hyper-arid climate. On average, the region typically receives not up to twenty-five millimeters (0.98 in) of downfall annually in sporadic patterns. Most of the rainfall happens throughout the winter months round the mountains. The presence of the mountains will produce a rain shadow, for the remainder of the Desert, conducive to the arid surroundings (Dorgham et al., 2019)

In the Cairo-Suez Desert, rainfall is characterized by its scantiness (25–30 mm year) and its great variability from year to year. Except for the winter months, the main part of the year is rainless, i.e. the climate is very arid. Cloudbursts may cause abundant rainfall within a limited area. The climate of this desert is classified as the Saharan-Mediterranean type of Emberger (1951).

According to the world DIVA-GIS (BIOCLIM database) (Hijmans et al., 2005) that we used to analysis the climate for study area recorded that: the area is situated within a region of dry climate. The mean annual precipitation is 1mm, with the rainy season stretching from October to May. The mean monthly air temperature ranges between 7.8 ºC during January and 36.6 ºC during August.

Data inventory and coolection

The present study was carried out from 2018 to 2023 during the spring season. A general survey and the line-intercept sampling technique were used to study the vegetation at different locations in the Cairo Petrified Forest protected area. The transects were identified, ensuring a reasonable degree of physiographic and physiognomic homogeneity of habitat and vegetation. Additionally, the list of species and their counts were recorded to determine the floral diversity.

Identification of plant species was carried out according to Täckholm (1974) and Boulos (1995; 1999, 2000; 2002, and 2005), and the diversity indices (Alpha diversity) were calculated at each site (Harper, 1999), These statistics apply to association data, where number of individuals are tabulated in rows (taxa) and possibly several columns (associations). The available statistics are as follows, for each association:

- Number of taxa (S)
- Total number of individuals (n)
- Dominance = 1-Simpson index. Ranges from 0 (all taxa are equally present) to 1 (one taxon dominates the community completely).

$$D = \sum_{1} \left(\frac{n_i}{n}\right)^2$$ where n_i is number of induviduals of taxon i.

- Simpson index 1-D. Measures 'evenness' of the community from 0 to 1. Note the confusion in the literature: Dominance and Simpson indices are often interchanged!
- Shannon index (entropy). A diversity index, taking into account the number of individuals as well as number of taxa. Varies from 0 for communities with only a single taxon to high values for communities with many taxa, each with few individuals.

$$H = \sum_{!} = \frac{n!}{n} \ln \frac{n!}{n}$$

- Buzas and Gibson's evenness: $\frac{eH}{S}$
- Brillouin's index: $HB = \frac{\ln(n!) - \sum \ln(n_1!)}{n}$
- Menhinick's richness index: $\frac{S}{\sqrt{n}}$
- Margalef's richness index: (S-1) / ln(n)
- Equitability. Shannon diversity divided by the logarithm of number of taxa. This measures the evenness with which individuals are divided among the taxa present.
- Fisher's alpha - a diversity index, defined implicitly by the formula S=a*ln(1+n/a) where S is number of taxa, n is number of individuals and a is the Fisher's alpha.
- Berger-Parker dominance: simply the number of individuals in the dominant taxon relative to n.
- Chao1, bias corrected: An estimate of total species richness. Chao1 = S + F1 (F1 - 1) / (2 (F2 + 1)), where F1 is the number of singleton species and F2 the number of doubleton species.

The research information resources were based on primary and secondary source, where the primary sources of information depending on field visits and semi-structured interviews; and the secondary sources of information depending on articles, reports, books, etc.

The research approaches are consisting of three main phases: Screening phase, mapping phase, reporting phase as following:

a) Screening and mapping Phases: During these phases, we organized for field visit with collect all the necessary information for identify the characterization of the study area plant diversity aspect, activities and stakeholders.

b) Reporting phase (data analysis): There many methods were used included: the SWOT stands for Strengths, Weaknesses, Opportunities, and Threats: SWOT tries to establish a strategic fit between an organization or units' internal strengths and weaknesses and opportunities and threats posed by its external environment (Beer et al., 2005). The method has its origins in the 1960s (Learned et al., 1965). This thinking has widely been accepted as a fundamental principle underlying modern strategic management (Beer et al., 2005). Venn diagram of stakeholders: a tool that helps to understand who will be affected by proposed development activities in the Potential Protected Area (FAO, 2001). It is used in this study to analyze links between most important stakeholders in the study area and their impacts on the nature vegetation.

RESULTS AND DISCUSSION

Vegetation cover

In total, 45 wild plant species representing 25 families were identified and recorded in the current study (Table 1). The present study documented the recorded species as follows: *Anthemis melampodina, Anabasis setifera, Atriplex lindleyi subsp.inflata, Bassia indica, Bassia muricate, Cakile maritima, Calligonum polygonoides, Calotropis procera, Centaurea pallescens, Cinnamomum camphora, Convolvulus lanatus, Cynanchum acutum, Deverra tortuosa, Diplotaxis acris, Diplotaxis harra, Erodium glaucophyllum, Erodium laciniatum, Fagonia indica,* *Fagonia mollis, Farsetia aegyptia, Forsskaolea tenacissima, Gypsophila capillaris, Agathophora alopecuroides, Haloxylon salicornicum, Launaea nudicaulis, Lycium shawii, Malva parviflora, Matthiola longipetala, Mentha longifolia, Mesembryanthemum forsskalei, Neurada procumbens, Pancratium sickenbergeri, Phragmites australis, Plantago cylindrica, Retama raetam, Rumex vesicarius, Schismus barbatus, Sonchus asper, Sorghum virgatum, Tamarix nilotica, Zilla spinosa, Zygophyllum coccineum, Zygophyllum dumosum, Zygophyllum simplex, and Euphorbia retusa.*

Table 1.

List of the plant species relative to there families that recorded in the study area

No.	Species	Family	Life form
1	*Anabasis setifera* Moq.	Amaranthaceae	Chamaephyte
2	*Anthemis melampodina* Delile	Asteraceae	Therophyte
3	*Atriplex halimus* L.	Chenopodiaceae	Phanerophytes
4	*Bassia indica* (Wight) A. J. Scott	Chenopodiaceae	Therophyte
5	*Bassia muricata* (L.) Asch.	Chenopodiaceae	Therophyte
6	*Cakile maritima* Scop.	Cruciferae	Therophyte
7	*Calligonum polygonoides* L. subsp. comosum (L' Hér.) Soskov	Polygonaceae	Phanerophytes
8	*Calotropis procera* (Aiton) W.T.Aiton	Asclepiadaceae	Phanerophytes
9	*Centaurea pallescens* Delile	Compositae	Therophyte
10	*Cinnamomum camphora* (L.) J.Presl	Lauraceae	Phanerophytes
11	*Convolvulus lanatus* Vahl	Convolvulaceae	Phanerophyte
12	*Cynanchum acutum* L.	Asclepiadaceae	Phanerophyte
13	*Deverra tortuosa* (Desf.) DC.	Apiaceae	Chamaephyte
14	*Diplotaxis acris* (Forssk.) Boiss.	Cruciferae	Therophyte
15	*Diplotaxis harra* (Forssk.) Boiss.	Cruciferae	Therophyte
16	*Erodium glaucophyllum* (L.) L'Hér.	Geraniaceae	Hemicryptophyte
17	*Erodium laciniatum* (Cav.) Willd.	Geraniaceae	Therophyte
18	*Fagonia indica* Burm.fil	Zygophylaceae	Hemicryptophyte
19	*Fagonia mollis* Delile	Zygophylaceae	Hemicryptophyte
20	*Farsetia aegyptia* Turra	Cruciferae	Chamaephyte
21	*Forsskaolea tenacissima L.*	Urticaceae	Chamaephyte
22	*Gypsophila capillaris (Forssk.) C.Chr*	Caryophyllaceae	Therophyte
23	*Agathophora alopecuroides* (Delile) Fenzl ex Bunge	Chenopodiaceae	Chamaephyte
24	*Haloxylon salicornicum* (Moq.) Bunge ex Boiss.	Amaranthaceae	Chamaephyte
25	*Launaea nudicaulis* (L.) Hook. f.	Compositae	Hemicryptophyte
26	*Lycium shawii* Roem. & Schult	Solanaceae	Phanerophyte
27	*Malva parviflora* L.	Malvaceae	Therophyte
28	*Matthiola longipetala* (Vent.) DC.	Brassicaceae	Therophyte
29	*Mentha longifolia* (L.) Huds	Labiatae	Therophyte
30	*Mesembryanthemum forsskalei* Hochst. Ex Boiss	Aizoaceae	Therophyte
31	*Neurada procumbens* L.	Neuradaceae	Therophyte
32	*Pancratium sickenbergeri* L.	Amaryllidaceae	Geophyte – Helophyte
33	*Phragmites australis* (Cav.)Trin. ex Steud.	Gramineae (Poaceae)	Geophytes Helophytes
34	*Plantago cylindrica*	Plantaginaceae	Therophyte
35	*Retama raetam* (Forssk.) Webb & Berthel. subsp. raetam	Fabaceae	Phanerophyte
36	*Rumex vesicarius*	Polygonaceae	Therophyte
37	*Schismus barbatus*	Gramineae	Geophytes Helophytes
38	*Sonchus asper* (L.) Hill.	Asteraceae	Therophyte
39	*Sorghum virgatum* (Hack.) Stapf in Prain	Gramineae (Poaceae)	Therophyte
40	*Tamarix nilotica* (Ehrenb.) Bunge	Tamaricaceae	Phanerophytes
41	*Zilla spinosa* (L.) Prantl in Engl. & Prantl	Cruciferae	Chamaephyte
42	*Zygophyllum coccineum* L.	Zygophyllaceae	Chamaephytes
43	*Zygophyllum dumosum* Boiss.	Zygophyllaceae	Chamaephytes
44	*Zygophyllum simplex* L.	Zygophyllaceae	Chamaephytes
45	*Euphorbia retusa* Forssk.	Euphorbiaceae	Therophyte

The plant species: *Bassia indica*, *Tamarix nilotica, Calotropis procera, Convolvulus lanatus, Cynanchum acutum, Malva parviflora, Mesembryanthemum forsskalei, Neurada procumbens, Phragmites australis, Plantago cylindrica, Sonchus asper, Zygophyllum coccineum and Zygophyllum dumosum* are the most abundant species recorded in the study area, and the most abundant plant families recorded were Zygophylaceae and Cruciferae (Table 2).

Table 2.
Total recorded families and number of species within each family, and their percentage within the study area

Family	No. Plant Species	% of Family
Aizoaceae	1	4
Amaranthaceae	3	12
Apiaceae	1	4
Asclepiadaceae	2	8
Asteraceae	2	8
Brassicaceae	1	4
Caryophyllaceae	1	4
Chenopodiaceae	4	16
Compositae	2	8
Convolvulaceae	1	4
Cruciferae	5	20
Euphorbiaceae	1	4
Fabaceae	1	4
Geraniaceae	2	8
Gramineae	3	12
Labiatae	1	4
Lauraceae	1	4
Malvaceae	1	4
Neuradaceae	1	4
Plantaginaceae	1	4
Polygonaceae	2	8
Solanaceae	1	4
Tamaricaceae	1	4
Urticaceae	1	4
Zygophylaceae	5	20

The number of flora species recorded in the study area was 34 in 2023, 30 in 2022, 28 in 2021, 28 in 2020, 38 in 2019, and 16 in 2018; these results are shown in Table 3. There are 11 plant species not recorded after 2019, after the boundaries were modified, such as: *Bassia muricate, Cakile maritima, Cinnamomum camphora, Diplotaxis acris, Erodium laciniatum, Fagonia indica, Fagonia mollis, Gypsophylla capillaris, Lycium shawii, Sorghum virgatum, and Zygophyllum simplex.*

Table 3.
The percentage composition of plant species in the study area and a comparison of 2023 with previous inventories in 2018, 2019, 2020, 2021, and 2022 (+ = recorded; - = not recorded)

Plant Species	2018	2019	2020	2021	2022	2023
Anabasis setifera	+	+	+	+	+	+
Anthemis melampodina	-	-	-	-	-	+
Atriplex lindleyi subsp.inflata	-	+	+	+	+	+
Bassia indica	+	+	+	+	+	+
Bassia muricata	-	+	-	-	-	-
Cakile maritime	+	+	-	-	-	-
polygonoides Calligonum	-	-	-	+	+	+
Calotropis procera	+	+	+	+	+	+
Centaurea pallescens	-	+	+	+	+	+
Cinnamomum camphora	-	+	-	-	-	-
Convolvulus lanatus	+	+	+	+	+	+
Cynanchum acutum	+	+	+	+	+	+
Deverra tortuosa	-	-	-	-	-	+
Diplotaxis acris	-	+	-	-	-	-
Diplotaxis harra	-	+	+	+	+	+
Erodium glaucophyllum	-	+	+	+	+	+
Erodium laciniatum	-	+	-	-	-	-
Fagonia indica	-	+	-	-	-	-
Fagonia mollis	-	+	-	-	-	-
Farsetia aegyptia	-	+	+	+	+	+
Forsskaolea tenacissima	-	-	-	-	+	+
Gypsophila capillaris	-	+	-	-	-	-
Agathophora alopecuroides	-	+	+	+	+	+
Haloxylon salicornicum	+	+	+	+	+	+
Launaea nudicaulis	-	+	+	+	+	+

Plant Species	2018	2019	2020	2021	2022	2023
Lycium shawii	-	+	+	-	-	-
Malva parviflora	+	+	+	+	+	+
Matthiola longipetala	-	-	-	-	-	+
Mentha longifolia	-	+	+	+	+	+
Mesembryanthemum forsskalei	+	+	+	+	+	+
Neurada procumbens	+	+	+	+	+	+
Pancratium sickenbergeri	-	-	-	-	-	+
Phragmites australis	+	+	+	+	+	+
Plantago cylindrical	+	+	+	+	+	+
Retama raetam	-	-	-	-	+	+
Rumex vesicarius	-	+	+	+	+	+
Schismus barbatus	-	+	+	+	+	+
Sonchus asper	+	+	+	+	+	+
Sorghum virgatum	-	+	-	-	-	-
Tamarix nilotica	+	+	+	+	+	+
Zilla spinosa	-	+	+	+	+	+
Zygophyllum coccineum	+	+	+	+	+	+
Zygophyllum dumosum	+	+	+	+	+	+
Zygophyllum simplex	-	+	-	-	-	-
Euphorbia retusa	-	+	+	+	+	+

Examination of more detailed diversity indices enhance the exploring of diversity in the Petrified Forest Protected Area. Table 4 shows different diversity indices along different years. The year of 2018 has the highest dominance value (=0.06) followed by year of 2020/2021 (=0.03). In contrary, the lowest Simpson's index value was recorded at year of 2018 (=0. 93) and highest at year of 2019 (=0.973). Similarly, the highest Shannon's diversity index value was at year of 2019 (=3.63) and lowest at year of 2018 (=2.77). The highest Buzas and Gibson's evenness index value was at year of (=1) and the lowest at stand 9 (=0.208). The highest Menhinick's richness index value was recorded at year of 2019 (=6.164) and the lowest at year of 2018 (=4). Meanwhile, the highest Margalef's richness index value was recorded year of 2019 (=10.17) and the lowest at year of 2018 (=5.41). However, Berger-Parker dominance was the highest at year of 2018 (=0.06), and the highest value of Chao1 index was recorded year of 2019 (=741).

Table 4.

Diversity indices along the study locations in the Petrified Forest Protected Area

Year	2018	2019	2020	2021	2022	2023
Taxa_S	16	38	28	28	30	34
Individuals	16	38	28	28	30	34
Dominance_D	0.0625	0.02632	0.03571	0.03571	0.03333	0.02941
Simpson_1-D	0.9375	0.9737	0.9643	0.9643	0.9667	0.9706
Shannon_H	2.773	3.638	3.332	3.332	3.401	3.526
Evenness_e^H/S	1	1	1	1	1	1
Brillouin	1.917	2.71	2.425	2.425	2.489	2.605
Menhinick	4	6.164	5.292	5.292	5.477	5.831
Margalef	5.41	10.17	8.103	8.103	8.526	9.358
Equitability_J	1	1	1	1	1	1
Fisher_alpha	0	0	0	0	0	0
Berger-Parker	0.0625	0.02632	0.03571	0.03571	0.03333	0.02941
Chao-1	136	741	406	406	465	595

Through the literature review, the Eastern Desert's northern sector between governorates of Cairo, Suez, and Qena, 124 perennial species such as *Zilla spinose, Zygophyllum coccineum, Pulicaria incisa,* and *Achillea fragrantissima* were reported by Fossati et al., (1998), while Khedr (2006) reported that, there are 540 wild plant species recorded in the north part of the Eastern Desert of Egypt. According to Zahran and Willis (2009), the vegetation of the Helwan Desert is made up of a permanent framework of perennials and complementary assemblages of therophytes. The structure of the vegetation varies in relation to three main physical features: (a) the extent of the catchment areas; (b) the nature of the surface deposits; and (c) the microclimatic conditions.

Moreover, there several studies recognized *Zygophyllum coccineum* as a community associated with *Zilla spinosa* (Kassas and Girgis, 1965; Abd El-Ghani, 1998), and Zahran and Willis (2009) reported that, within the limestone country of Helwan Desert the *Zilla spinosa* community is widespread. It occurs in parts of the wadi bed where the alluvial deposits have a high proportion of soft ingredients, unlike the *Zygophyllum coccineum* community which is restricted to the Eocene limestone country. Additionally, monotypic communities of the dominant species were recorded in the study area (Fossati et al., 1998), and the *Zygophyllum coccineum-Zilla spinosa* vegetation group is mainly characterized by soil rich in sand contents and calcium carbonates, with low values of salinity (Hegazy et al., 2004).

On the other hand, The *Tamarix nilotica* scrubland is considered one of the climax types of vegetation in the desert wadis, and the phytocoenosis dominated by *Tamarix nilotica* includes *Zygophyllum coccineum* and *Zilla spinosa* are common associates (Girgis, 1962). Additionally, the *Zygophyllum coccineum* community appears to occupy the beds of the wadis where Middle Eocene nummulitic hard limestone forming the floor is covered by shallow alluvial detritus. The *Anabasis setifera* community occurs in comparable parts of wadis where marly limestone (mostly Upper Eocene) forming the fl oor is covered by a veneer of alluvial rock detritus (Zahran and Willis, 2009).

Moreover, Kassas and Zahran (1971) reported that, the ecological set up of the coastal hills and mountains demonstrate the influence of orographic precipitation on the plant growth. In this respect the physiographic features become of foremost importance. In such situation the vegetational pattern is different from that of the arid countries, and Boulos (2008) recorded 40 species in both sides of the Gulf of Suez: the northern mountains and wadis of the Eastern Desert (west of the Gulf of Suez) and Sinai (east of the Gulf of Suez), these are not known elsewhere in Egypt. Moreover, The *Anabasis setifera* community replaces that of *Zygophyllum coccineum* in several areas of Helwan Desert such as Petrified Forest, where the structure of this community bears some resemblance to that of *Zygophyllum coccineum,* and both of the dominants are succulent perennials but *Anabasis setifera* is a winter deciduous plant with the whole of its shoot drying up during the winter, and *Zygophyllum coccineum* is an evergreen (Zahran and Willis, 2009).

Due to IUCN habitats classification scheme: the desert consists of arid landscapes with a sparse plant cover, except in depressions where water accumulates. The sandy, stony or rocky substrate contributes more to the appearance of the landscape than does the vegetation (IUCN, 2014).

The desert of Petrified Forest in consists of arid vegetation (xerophytic and halophytic plants) with a sparse plant cover. Although poor in species, the vegetation of the the study area was composed of (45) plant species belonging to (25) families were recorded.

The national phytogeographical distribution of the plant species has shown that most plant species in the study area have a wide geographical distribution in Egypt. The maximum frequencies for the species have a distribution to the eastern desert region in Egypt, oases region and desert region. While the global distribution of the plant species showing that the majority of recorded species belong to the Saharo-Arabian region. Abd El- Ghani and Amer (2003) mentioned that the plants of the Saharo-Arabian species are good indicators for desert environmental conditions.

General threats and status understands

The present study recorded that the major human pressures in the Petrified Forest Protected Area included: vehicle disturbance and trampling, economic activities (restaurants and shops), new residential projects (urbanization and infrastructure), and current and future highway construction.

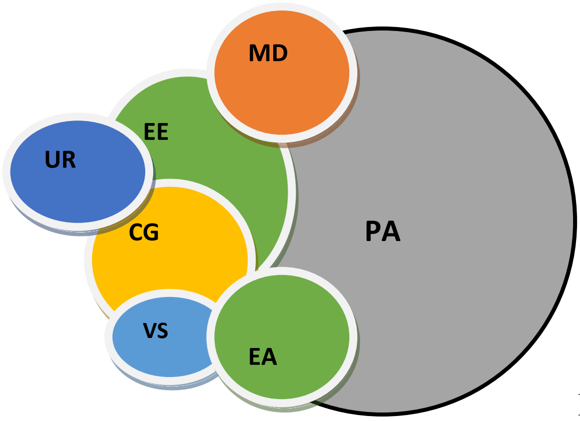
SWOT analysis method aims to identify the key internal and external factors facing the conservation of biodiversity at an area. Table summarizes those factors (strengths, weaknesses, opportunities and threats) in the study area (Table 5).

Table 5.

SWOT analysis for plantlife conservation

Element	Positive	Negative
Internal	**Strengths** - Possibility of enforce the rules of the protected area. - Availability of a preliminary "master plan" in order to protect of biodiversity.	**Weaknesses** - A lack of funding for implemented the biodiversity conservation plans - Weak law enforcement - Shortage of awareness and education programs to local visitors and civil society - The relations with main stakeholders.
External	**Opportunities** - Law 102 /1983 for protected areas and 9/2009 for Environment. - Located the area in new Cairo. - Implement visitor's awareness / education programs to promote the unique ecosystems and environmental qualities and characteristics in the area. - Possibility of establish a zontion system to protect the vegetation cover and fosils sites.	**Threats** - The negative human impacts such as disturbance by cars or trampling, the economic activities (restaurants), the new residential projects, plans for establish of future car roads.

The Venn diagram tool aims to analyze the degree of linkage between different stakeholders in the Petrified Forest Protected Area. Most stakeholders in the study area play direct or indirect roles, either affecting or being affected by ecosystem and biodiversity conservation actions (Figure 2). Results from semi-structured interviews and meetings with key informants highlight a lack of active stakeholder cooperation in the Petrified Forest, as well as the need for enhanced collaboration between these stakeholders and the Nature Conservation Sector (NCS) of the Egyptian Environmental Affairs Agency to develop measures for future cooperation.



Legend

PA	Protected Area
EE	Egyptian Environmental Affairs Agency
CG	Cairo Governorate (New Cairo Agency)
VS	Visitors
MD	Ministry of Defense
EA	Privite Economic Activities
UR	Universities and Research Institutions

Fig. 2. Venn diagram of stakeholders.
Note: The circles placed as follows: separate circles = no contact; touching circles = information passes between institutions; small overlap = some co-operation in decision making and large overlap = a lot of co-operation in decision making.

The protected area plays a vital role in fostering cooperation among government authorities and local business owners. The Egyptian Environmental Affairs Agency, the Ministry of Defense, and local business owners are the three key actors affecting biodiversity in the area. The primary threats to future conservation plan in the study area stem from a lack of public awareness, weak law enforcement, and a lack of interest in stakeholder cooperation.

Perceptions of local visitors and local authorities' attitudes towards protected areas and conservation activities. Most respondents held a positive attitude towards protected areas and the analysis of their attitudes and perceptions revealed potential conflicts that might affect biodiversity conservation and future management of protected area. The results of this study agrees with several authors (Cihar and Stankova, 2006; Bennett and Dearden, 2014) that the public perceptions, needs and preferences with regard to environmental quality should be added to any evaluation in order to produce and improve the planning process, and with (Roca et al., 2009) that, comprehensive and meaningful information on how local communities/residents perceive protected areas and their management is valuable and can be effectively used to plan a better environmental management and eventually develop sustainable tourism. However, the conservation initiatives require an active participation of local communities in decision making processes and solutions to integrate local development with environmental conservation (Gerhardinger et al., 2009; Xu et al., 2006).

According to TNC (2000), TNC's 5-S Framework describes four variables used to measure threats including low, medium, high and very high ranks (Table 6).

Table 6.

Describes the four variables used to measure threats at flora in the study area

Threats	Location			
	Northeast section	Northwest section	Southwest section	Southeast section
Urbanization and Infrastructure (Restaurants, residential projects)	**Very high**	**Very high**	**Medium**	**High**
Disturbance by cars or trampling (irresponsible visiting)	**Low**	**High**	**Medium**	**Low**
Autostrad and highway roads	**Very high**	**Low**	**Very high**	**Very high**

Conservation action

Through review the global experiences for management of protected areas, the World Commission on Protected Areas (WCPA-IUCN) characterizes a protected area system as having five linked elements (Dudley, 2008) can describe as following:

- Representativeness, comprehensiveness and balance: including highest quality examples of the full range of ecosystems and environment types within a country; includes the extent to which protected areas provide balanced sampling of the environment types they purport to represent.
- Adequacy: integrity, sufficiency of spatial extent and arrangement of contributing units, together with effective management, to support viability of the environmental processes and/or species, populations and communities that make up the biodiversity.
- Coherence and complementarily: positive contribution of each protected area towards the whole set of conservation and sustainable development objectives defined.
- Consistency: application of management objectives, policies and classifications under comparable conditions in standard ways.
- Cost effectiveness, efficiency and equity: appropriate balance between the costs and benefits.

Furthermore, the conservation of the biodiversity and ecosystems in the study area requires prepare a management plan, where the protected area should aim to maintain the biodiversity and structure and function of ecosystems; contribute to conservation strategies at national and international level (Dudley, 2008). The management plan should address many activities and programs as following:

I. Establishment of monitoring program: is important to assess the current condition and any changes that may affect the natural resources. The usefulness of this network is to feed a local data bank with up-to-date information on the status of biodiversity and any other elements that may affect the natural resources health.

II. Establishment of Reference Collections and Data Bank: This activity can be presented at the future Protected Area’s visitor center. Reference collections will include flora (herbarium) and geology and soil types can be built, kept and updated through the scientific surveys. A data bank is a computerized depot for data on biodiversity (with its various elements), ecological monitoring and research results. It will also contain a geographical information system (GIS) database for area. This will be, eventually, a part of the national database of protected areas and biodiversity at the Egyptian Environmental Affairs Agency (EEAA). Also, the data bank will store periodical reports on the status of conservation and sustainable use of natural resources.

III. Research and Studies Program: There is a need for research work on population- and ecosystem dynamics, assessment of ecological changes, environmental impact studies related to new development schemes need to be carried out.

IV. Rehabilitation program: Vegetation conservation urgently needs the evaluation of the success of rehabilitation trials implemented in other Egyptian protected areas network. This may help to establish a rehabilitation program in the area (rare plants) to contribute in success of future conservation activities.

V. Public Awareness program: The purpose of this activity is to raise the awareness of people (of all ages) to ensure their support to, and participation in, the operations of the Protected Area and, in particular, the conservation of natural vegetation.

The ecological importance of Wadi plants extends to their role as genetic resources for drought and heat tolerance, offering insights into adaptive mechanisms under climate change scenarios (Ullah et al., 2019). Additionally, these plant species support biodiversity by serving as keystone resources for pollinators and herbivores, which are integral to desert food webs (Guo-Cui et al., 2024). Ethnobotanical studies further highlight their socio-economic value, as many species are utilized by indigenous and local communities for traditional medicine, fodder, and fuel, underscoring the interdependence between human livelihoods and plant conservation (Ralte et al., 2024; Gawai and Tippat, 2024).

The sustainable management of the floral biodiversity requires stopping the severe human impacts that lead to eliminating certain plant populations and modifying the complex plant communities into simple fragile onces (Afefe, 2020; Abbas et al., 2016). Where, the despite the fact that the legal requirements for the protection of the wild flora in the the current Protected Area are present, the Habitats Change / Destruction by lack of the demarcation and the increase of human pressures such as urbanization and infrastructure will led to lose of the biodiversity isuuse (Afefe, 2021a; Afefe et al., 2016)

Environmental deterioration, habitat changes, inappropriate vegetation management, translocation, fragmentation, and deforestation modify biotic and abiotic ecosystem components, resulting in changes in ecological processes such as vegetation dynamics (Referowska, 2019; Newton et al., 2009; Kapos, et al., 2002). Road building, overharvesting, solid wastes, salinization, industrialization, urbanization, and military activities are considered to be the main anthropogenic activities that lead to changes and transformation of vegetation and natural habitat loss in arid and semi-arid environments (Moustafa et al., 1999; Nakahama et al.,2015; Hussein et al.,2021).

Futhermore, in terrestrial ecosystems, Biodiversity decline is influenced by various types of human activities, including land cover changes, the introduction of invasive species, overexploitation, and pollution (Sebastian et al., 2015; Pereira et al., 2012; Zhu et al., 2019).

Additionally, Population growth and urbanization are the most important causes of ecosystems collapse (UN, 2017), where, rapid population growth leads to many problems such as fire prevalence, air pollution, light pollution, loss of genetic diversity, the prevalence of invasive species, and wildlife destruction (Finn and Stephens, 2017).

Moreover, Geldmann et al. (2013) analyzed of 76 studies at local and global scales indicates that the protected areas experience lower rates of habitat loss than areas that are not protected, and the majority of habitat studies suggest that the effect size of protection is small: protected areas may be reducing the rate of decline compared to counterfactuals, but where external threats are high Protected Areas are still experiencing dramatic habitat losses within their borders, for species populations, the effect of protection is unclear.

However, the studies that Geldmann et al. (2013) compiled lend some support for protected areas being effective, but are not unanimous. This highlights the importance of monitoring in protected area management and decision-making without monitoring we cannot manage effectively (Stem et al., 2005). The majority of publications do show at least some positive impact of protection, but poor sample size, and bias in geography and taxonomy make generalization unwise. Investment in antipoaching appears to be very effective; however, given the limited sample, it is impossible to tell whether publication bias has resulted in only positive or complex outcomes being reported, biasing this conclusion.

The International Union for Conservation of Nature (IUCN) has suggested that the long-term success of in-situ conservation requires that the global system of protected areas comprise a representative sample of each of the world's different ecosystems (Davey, 1998). Human impact has been recognized as the most important influence on the composition of the flora and vegetation during the last 5000 years. This impact has been a dominant environmental factor in the arid environments of the world, particularly in the Middle East for thousands of years (Zohary, 1983). The world's landscapes are now occupied by humanaltered (and in part by human-created) floras. Humans have been the primary agent in the creation of new plant communities (Anderson, 1956). Since human activities have a strong effect on biodiversity, community level approach is considered to be the level that can help in exploring the responses of the whole ecological system to various kinds of disturbance (Barbault and Hochberg, 1992). It has been stressed that special attention should be paid to habitat disturbances in biodiversity research because the populations of many species are being turned into metapopulations as a result of habitat fragmentation (Hanski and Gilpin, 1991). This landscape ecological level view has become a central focus point in conservation biology and biodiversity research (e.g. Hanski and Gilpin, 1991). Human impacts can alter the abundance of palatable and unpalatable species, and of woody versus herbaceous cover, in a variety of ways (Ali et al., 2000). However, The Convention on Biological Diversity (CBD) defines the ecosystem approach as: a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way (CBD, 2014). The overriding purpose of a system of protected areas is to increase the effectiveness of in-situ biodiversity conservation. The present study agrees with Afefe (2021b), the plant life in the coastal desert wadis and mountains of the Eastern Desert is rather rich and interesting, and Considerations of the exploitation and conservation of wild plants must be take ecological principles into account through requires stopping the severe human impacts.

CONCLUSIONS

In conclusion, the plant life in the Eastern Desert of Egypt is rather rich and interesting. This paper makes a significant contribution by providing an overview of the conservation planning process for the vegetation cover in the Petrified Forest Protected Area in Egypt. The outcomes of this study will aid in the implementation of necessary environmental protection measures, and the study clearly shows changes in wild flora communities in the Petrified Forest Protected Area between 2018 and 2023. Sustainable management of the biodiversity in the study area requires stopping the severe human impacts that lead to the elimination of certain plant populations, and hence the modification of complex plant communities into simple, fragile ones.

AUTHORS CONTRIBUTIONS

Conceptualization, Abdelwahab A. Afefe; methodology and data collection, Reda A. Abu-moustafa; data validation, Abdelwahab A. Afefe, ; data processing, Abdelwahab A. Afefe; writing—original draft preparation Abdelwahab A. Afefe; writing—review and editing, Abdelwahab A. Afefe and Reda A. Abu-Moustaf.

CONFLICT OF INTEREST

The authors do not have any competing financial, professional, or personal interests from other parties.

FUNDING

This research received no external funding.

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