The 7th Conf. of SSFOP "A Recent Strategy for Ornamental Plants Production"
Cairo, Egypt, 19/2/2023
Scientific J. Flowers & Ornamental Plants
www.ssfop.com/journal
ISSN: 2356-7864 **doi: 10.21608/SJFOP.2023.301848**

EVALUATING THE BIODIVERSITY AND CONSERVATION APPROACH OF WOODY TAXA IN GIZA ZOO, EGYPT

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Scientific J. Flowers & Ornamental Plants, 10(1):71-89 (2023).

Received:
1/2/2023
Accepted:
17/2/2023

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ABSTRACT: This is the first study to measure the diversity of woody taxa in Giza Zoo garden considered an extraordinarily diverse hotspot with an unusually high number of woody taxa found nowhere else in Egypt especially, tropical species. This study was conducted in several stages, preparation, inventory, analysis, and evaluation. The study uses quantitative methods to evaluate the woody taxa diversity and the threatened species which are conserved in the garden across their main sections. Therefore, species richness, Shannon and Simpson's diversity indices were estimated. Also, the species importance value index, a measure of how dominant a species is in a given population, and conservation status were used to evaluate the conservation potential of the trees in the garden. The garden plays a vital role in conserving 145 individuals as threatened trees belonging to 18 species that are either endangered, near threatened or vulnerable according to the IUCN red list. The Weak conservation procedures in the zoo garden have led more individuals of species that are over-mature and over-aged to their demise therefore, it is feared that may be lost from the garden. So, it's imperative to immediately restore these lost species in the garden and place their diversity on a pathway to recovery. We warn to increase the area of impermeable pathways and more buildings that will increase the stresses upon the garden trees. Therefore, we suggest technical support for the botanic garden as the experts of the Timber Trees department will be essential for allowing this valuable garden to continue its work and expand its collections of critical but under-represented species. Also, the inventory of tree species entity and structure in this study will assist as a guide tool for the administration of the garden to reach the Egyptian sustainable development goals by 2030 and the global goals by 2050.

Keywords: Giza Zoo garden; diversity; richness; Shannon-weaver index; Simpson's index; trees.

INTRODUCTION

Designing and planning cities with nature-positive interventions are arguably one of the most feasible approaches for tackling biodiversity loss. Therefore, it could be achieved by integrating and conserving nature in the botanic gardens. The botanical garden is not just an attractive area for picnics however, it is an important area that exhibits plant diversity and permits researchers to innovate and recommend new techniques to protect and grow up biodiversity in a world where the planet's flora resources are threatened at an unprecedented rate. For instance, the Royal botanical garden is visited by more than a million tourists each year and hosts the world's largest and most diverse collection of living plants and is home to over 28,000 taxa of living plants and 30,000 species of plant seeds. As well, botanical gardens play a major role in tree species conservation but identify actions to enhance future conservation of biodiversity. The world's botanical gardens contain a wide range of plant species, with 41% of those categorized as "threatened" (Mounce *et al*., 2017). Botanic gardens conserve plant diversity ex-situ and can prevent extinction through integrated conservation action. Here we quantify how that diversity is conserved in ex-situ collections across the world's botanic gardens. We reveal that botanic gardens manage at least 105,634 species, equating to 30% of all plant species diversity, and conserve over 41% of known threatened species. While botanic gardens are discernibly responding to the threat of species extinction, just 10% of network capacity is devoted to threatened species. Mounce *et al*. (2017) discovered that over half of all plant genera can be found outside of their habitats in botanic gardens. Nevertheless, while a temperate species has a 60% chance of being collected and held by botanic gardens, those odds collapse to 25% for a tropical species, which may reflect the high expenditures to conserve tropical species ex-situ. The Conference of the Parties set out the process for developing a post-2020 global biodiversity framework to reduce threats to biodiversity. The framework aims to ensure that at least 30% globally of land areas, especially areas of particular importance for biodiversity and its contributions to people, as Giza Zoo botanic garden in Egypt, are conserved through effectively and equitably managed, ecologically representative and well-connected systems of protected areas and other effective area-based conservation measures, and integrated into the wider landscapes (CBD, 2021). On the other hand, Wilcove (2010) suggests three stages for conserving the threatened species (i) identifying the threatened species, (ii) determining and executing short-term measures to stop the decline of the species and then recovery, and (iii) defining and applying longer-term measures to reestablish viable populations. Species diversity involves two indices: species richness and species evenness. Species richness is the number of species per area (geo-botanical situation) whereas, Evenness is the abundance situation of species in a community. Species richness is an important property of ecological systems which can contribute to the resilience of the biological component of the system (Folke *et al*., 1996), which influences people's health and wellbeing (Fuller *et al*., 2007) and support to form people's experience of biological life (Miller, 2005). There is a positive correlation between these two indices; however, high species richness is not necessarily escorted by high-degree evenness. The IUCN red list is a critical indicator of the biodiversity status of the world flora. More away than a species list and its status, it is a sturdy tool to inform and initiate action for biodiversity conservation and policy modification. It is used by government agencies, wildlife departments, conservation-related non-governmental organizations (NGOs), natural resource planners, educational organizations, students, and the business community.

The aim of this work is to quantify the woody taxa diversity and the threatened species which are conserved in Giza Zoo across the main sections of the garden.

MATERIALS AND METHODS

Study site:

Giza Zoo is a botanical garden that is located near the west bank of the Nile (latitude 30° 01′ 45.12″ N, longitude 31° 12′ 47.16″ E) in the Giza governorate, Egypt. It is the third oldest in the world and the first in Africa founded by Khedive Ismail in 1891. It is about 81 feddans in an area that was once part of the harem gardens. Ismail imported many plants from India, Africa, and South America. Giza has a desert climate. There is virtually no rainfall all year long in Giza. The climate of the study area is classified as a hot desert climate by the Köppen-Geiger system (Aparecido *et al*., 2016). The average annual temperature is 22.5 °C, the annual rainfall is

18 mm (Fig., 1) and the soil is a clayey texture.

Methods:

The distribution data on trees and shrubs were compiled manually from January up to October 2022. The woody taxa's data collection was performed within three sections; S1, S2 and S3 (Fig., 2). Whereas, their borders were aligned with the nearest pathways in the garden so the areas of the three sections were (24.8, 29.7 and 26.5 feddans, respectively). For each section, the woody plant numbers (abundance) were enumerated and the number per feddan (density) was detected. The woody plants of the garden were assigned then the total height of the tree or the shrub (m) was measured using (Suunto PM-5/360PC) Clinometer. The circumferences (cm) of all trunks were measured and converted to diameters at breast height (dbh). The total height was partitioned into 3 layers as: emergent (>20 m), understory (6-20 m) and suppressed (<6 m). Likewise, the dbh was partitioned into 5 classes (<25, 25-50, 51-100, 101-200 and >200 cm). The status of all trees was visually evaluated and classed into (good, weak and dead). Data collection was accomplished with the assistance of skilled staff and reviewed with the herbarium records of the Giza Zoo botanic garden. The scientific names were updated through POWO (2022) database which is sourced from the Royal Botanic Gardens, Kew. Two individuals of *Acacia* and 15 of *Ficus* in the garden were unassignable to species or morphospecies. These unidentified individuals were lumped together into unknown genera as *Acacia spp*. and *Ficus spp*., respectively.

The computations of the following growth parameter and biodiversity indices [The basal area of all trees in the garden (BA), species relative density (RD), species relative dominance (RD_o) and the importance value index (IVI) of each species] were estimated according to Bahnasy and Khamis (2019). Diversity measures encompasses species richness (the number of species) and evenness (equitability in species abundances) were calculated. The Shannon diversity index (*H'*) was applied as a measure of species abundance and richness to quantify the diversity of the tree species. This index takes

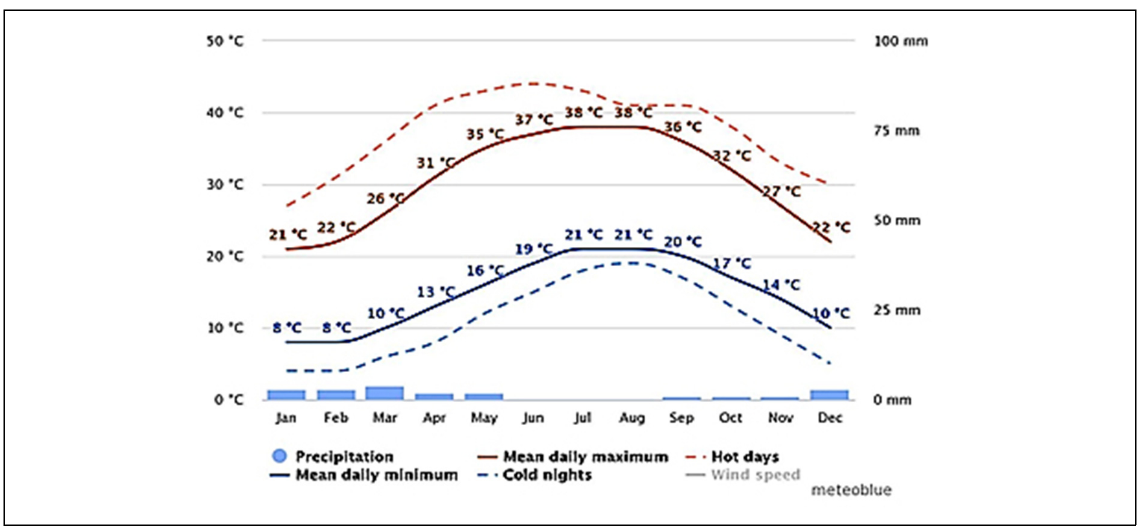

Fig. 1. The mean daily maximum (solid red line) shows the maximum temperature of an average day for every month in the Giza governorate. The mean daily minimum (solid blue line) shows the average minimum temperature. Hot days and cold nights (dashed red and blue lines) show the average of the hottest day and coldest night of each month of the last 30 years (source: https://www.meteoblue.com).

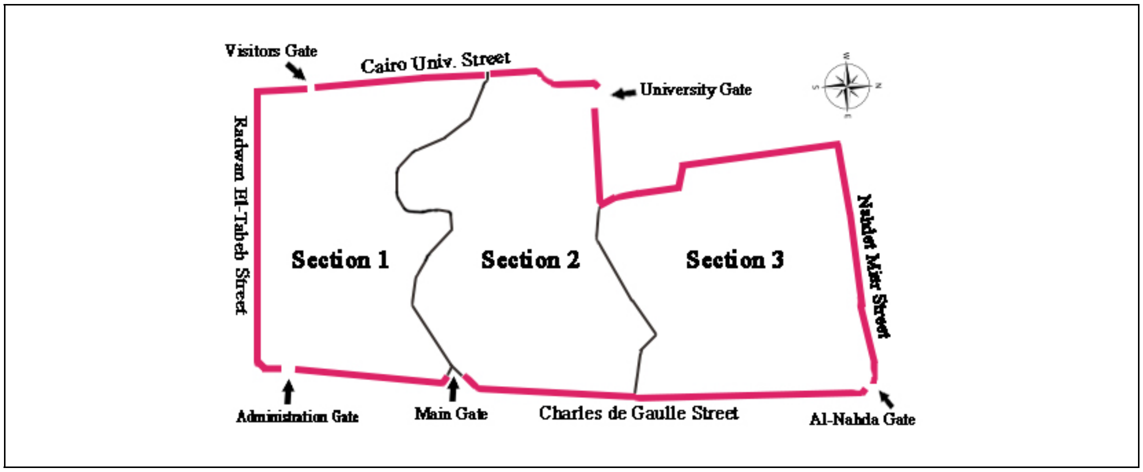

Fig. 2. Map of Giza Zoo Botanical Garden showing the three sections in the present study.

both species abundance and species richness into account:

$$H' = \sum_{i=1}^{s} pi \ \text{In} \ pi'$$

Where: *s* equals the number of species and *pi* equals the ratio of individuals of species *i* divided by all individuals *N* of all species.

Statistical analysis:

Descriptive statistics as total number (No.) means, standard deviation (SD.), maximum (Max.) and minimum (Min.) of all tree species were calculated for the whole area of Giza Zoo botanical garden. The data were processed with ComEcolPaC-1.0 program to calculate common parameters of the community and various diversity indices (Pinheiro *et al*., 2022). Also, the similarity index between the three sections was computed using Jaccard and Renkonen indices.

RESULTS AND DISCUSSION

Garden entity:

In general, the Giza Zoo's garden entity was identified based on quantitative aspects of abundance (A), height (H), diameter at breast height (dbh), and basal area (BA) while the general status of woody taxa was identified based on qualitative aspects. The area of the three sections ranged from 24.8 to 29.7 feddans with a mean of 27.0 (±2.49) feddans. Table (1) shows that a total of 1773 individual trees in the garden representing 202 species belonging to 50 families were identified in these sections.

Furthermore, Fig. (3) illustrates that Moraceae is the highest dominant family in Giza Zoo botanical garden with 34% (605 individuals), followed by Fabaceae, Malvaceae, Myrtaceae, Meliaceae, Cupressaceae, Bignoniaceae, Combretaceae, Casuarinaceae, Anacardiaceae, Bombaceae, Euphorbiaceae, Sapindaceae, Sapotaceae, Simaroubaceae and Apocynaceae with 579, 88, 74, 57, 44, 43, 37, 26, 25, 25, 17, 15, 13, 12 and 11 individuals, respectively. Then, another 22 families were represented by 8-2 individuals and 10 families were represented by only one individual (Annonaceae, Araliaceae, Bixaceae, Loganiaceae, Lythraceae, Malpighiaceae, Phytolaccaceae, Platanaceae, Rubiaceae and Scrophulariaceae). These results are nearly similar to those of Bahnasy and Khamis (2019) in Orman Garden, Diwan *et al*. (2004), Abd El Hady (2007), Abd El Migid and Diwan (2014) and Hamdy *et al*. (2007). The dominance of the Moraceae and Fabaceae families was mainly due to the high species richness, abundance, and basal area of the constituent species.

Additionally, Fig. (4) exhibits that the understory layer that ranges 6-20 m in height represents 73% of woody trees in the garden

Table 1. Average Count, Mean, standard deviations (SD), maximum (Max) and minimum (Min) values of section (area and density) and the total number of species and families in Giza Zoo's botanical garden.

Section parameters	Count	Mean (SD)	Max	Min
Area (feddan/section)	3	27.0 (±2.49)	29.7	24.8
Density (tree/feddan)	3	22.63 (±8.14)	31.33	15.19
Total no. of individuals	1773			
Total no. of families	50			
Total no. of species	202			

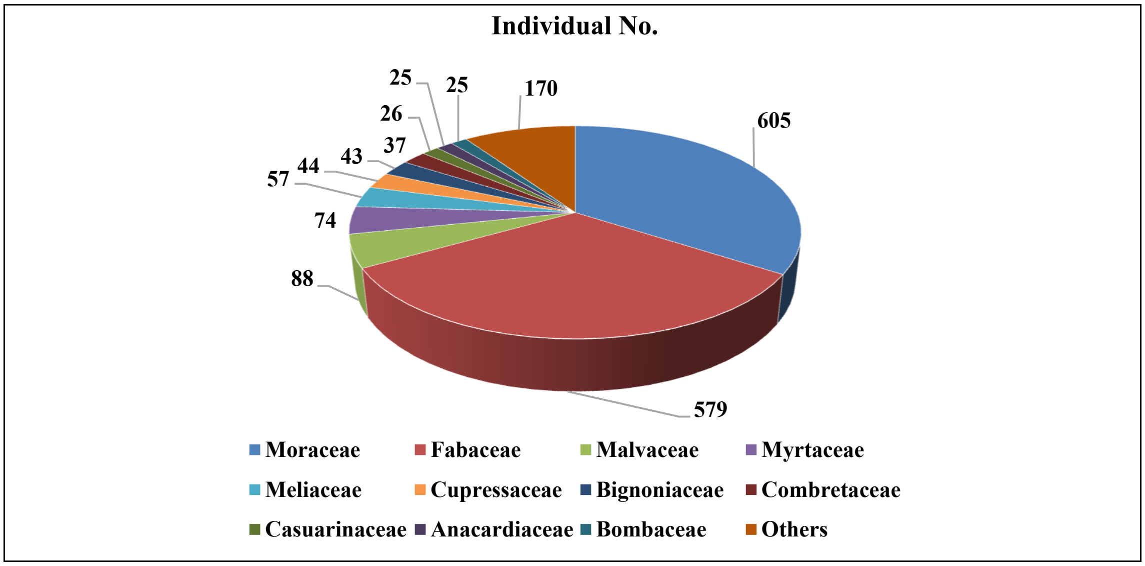

Fig. 3. Individual count of each family member in Giza Zoo garden.

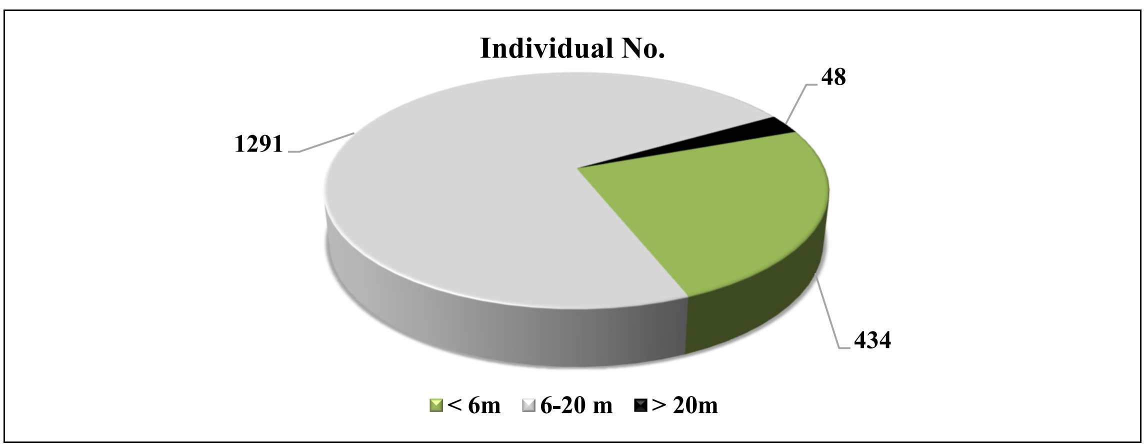

Fig. 4. Individuals count of woody taxa in Giza Zoo garden partitioned in 3 layers of height (< 6, 6-20 and >20 m).

(1291 individuals). Also, 3% of the trees are more than 20 m in height (48 individuals) and represent the emergent layer besides 24% are less than 6 m in height (434 individuals) and represent the suppressed layer. The emergent layer of tree species in the garden is presented in Table (2). The tallest trees in section 1 and section 3 are represented by two species (*Eucalyptus camaldulensis* and *Ficus religiosa,* 30 m in height per each). The lonely tallest tree in section 2 is *Ficus religiosa* (30 m in height). On the other hand, 9 individuals only are more than 200 cm in dbh and 350 are less than 25 cm in dbh then, 42% of them ranged from 25-50 cm in dbh (749 individuals) (Fig., 5). The huge trees in section 1 and section 2 are *Ficus benghalensis* (308.3 and 300.0 cm dbh, respectively) whereas, the only huge one in section 3 is *Ficus religiosa* (238.8 cm dbh) (Table, 3). The abundance ranged from 451 to 777 trees/section with a mean of 598 (±165.3)/section. Moreover, the density ranged from 15.19 to 31.33 trees/feddan with a mean of 22.63 (±8.14) trees/feddan (Table, 1).

Table (3) shows that the garden has nine huge trees, their diameters are more than 200 cm, and the widest species is *Ficus benghalensis* represented by one individual in section 1 and another two individuals in section 2 (308.3, 300, and 220 cm in diameter, respectively). The next widest species is *Ficus religiosa* represented by two individuals in section 1, two individuals in section 2, and one individual in section 3. It is noticed that the above-mentioned widest species belongs to the Moraceae family.

Table 2. The tallest trees (>20 m) in Giza Zoo garden with their location and belonging families.

S1 Species	H (m)	S2 Species	H (m)	S3 Species	H (m)
Fabaceae		**Combretaceae**		**Fabaceae**	
Tipuana tipu	22	*Terminalia arjuna*	22	*Tipuana tipu*	22
Meliaceae		**Fabaceae**		**Meliaceae**	
Khaya senegalensis	25	*Tipuana tipu*	23	*Khaya senegalensis*	25
Khaya senegalensis	25	*Acacia arabica var. nilotica*	22	*Khaya senegalensis*	25
Khaya senegalensis	25	*Tipuana tipu*	21	*Khaya senegalensis*	25
Khaya senegalensis	22	**Malvaceae**		*Khaya senegalensis*	22
Khaya senegalensis	22	*Bombax ceiba*	22	*Khaya senegalensis*	22
Moraceae		**Meliaceae**		**Moraceae**	
Ficus religiosa	30	*Khaya senegalensis*	28	*Ficus religiosa*	30
Ficus religiosa	21	*Swietenia mahagoni*	25	*Ficus religiosa*	21
Myrtaceae		**Moraceae**		**Myrtaceae**	
Eucalyptus camaldulensis	30	*Ficus religiosa*	30	*Eucalyptus camaldulensis*	30
Eucalyptus camaldulensis	27	*Ficus religiosa*	25	*Eucalyptus camaldulensis*	27
Corymbia citriodora	23	**Myrtaceae**		*Corymbia citriodora*	23
Eucalyptus camaldulensis	22	*Eucalyptus camaldulensis*	27	*Eucalyptus camaldulensis*	22
Eucalyptus camaldulensis	22	*Eucalyptus camaldulensis*	25	*Eucalyptus camaldulensis*	22
Eucalyptus camaldulensis	21	*Eucalyptus camaldulensis*	22	*Eucalyptus camaldulensis*	21
Eucalyptus camaldulensis	21	*Eucalyptus camaldulensis*	21	*Eucalyptus camaldulensis*	21
Corymbia citriodora	21			*Corymbia citriodora*	21

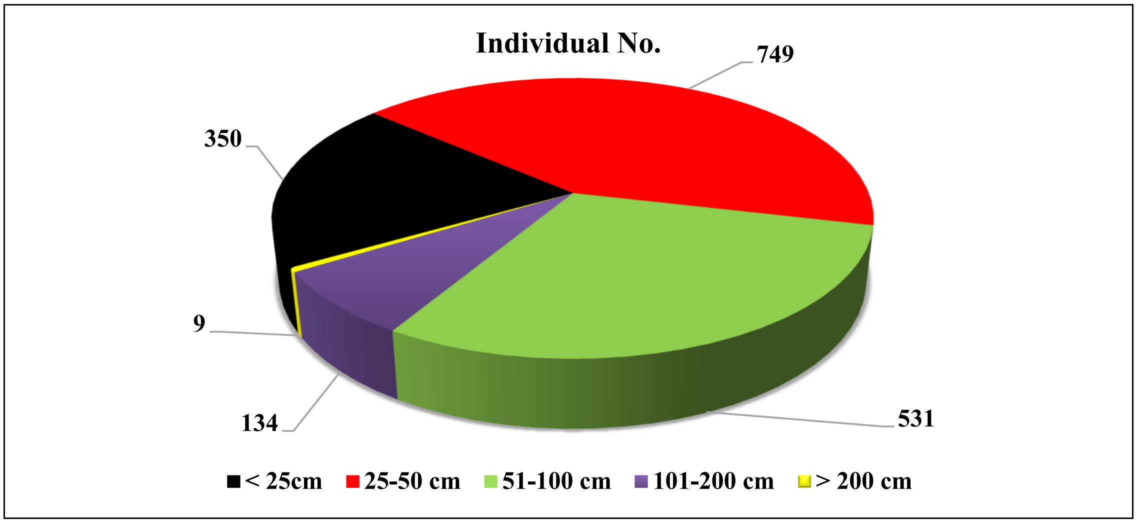

Fig. 5. Individuals count of woody taxa in Giza Zoo garden partitioned in 6 classes of diameter at breast height (<25, 25-50, 51-100, 101-200 and >200 cm).

Table 3. The huge trees (>200 cm in diameter) in Giza Zoo garden with their location and belonging families.

S1		S2		S3	
Species	dbh (cm)	Species	dbh (cm)	Species	dbh (cm)
Moraceae		**Moraceae**		**Moraceae**	
Ficus benghalensis	308.3	*Ficus benghalensis*	300.0	*Ficus religiosa*	238.8
Ficus religiosa	238.8	*Ficus religiosa*	238.8		
Ficus religiosa	210	*Ficus religiosa*	220		
Putranjivaceae		*Ficus benghalensis*	220		
Putranjiva roxburghii	204.77				

Also, the garden has one individual of *Putranjiva roxburghii* species belonging to the Putranjivaceae family which is located in section 1 and reached 204.77 cm in diameter.

Diversity:

Table (4) shows the estimation of the importance value index (IVI) exceeding 1.0 for tree species in the garden. Results are ordered from the highest to lowest value. High IVI does not mean that these tree species currently dominate the structure of the Giza Zoo garden but shouldn't necessarily be encouraged in the future. Also, results show that the higher existing relative density (RD_i), for the whole garden, was 25.76 and 22.40% for *Ficus microcarpa* and *Delonix regia* with 460 and 400 individuals, respectively. On the other hand, the higher relative dominance (RD_o) was detected for *D. regia* (15.07%) and followed by *F. microcarpa* (11.84%). Therefore, the higher IVI was recorded for *F. microcarpa* and *D. regia* with 18.80 and 18.73. The results of the present study indicated that the maximum height and individual number determine the dominance of tree species in the garden. As well as, switching the rank between RD_i, from one side, and both RD_o and IVI from another side as the RD_o and IVI are concerned with basal area. At the same time, the basal area depends on the size of the trees, and the species of these trees as explained by Ducey and Knapp, (2010). Also, the higher RD_o of *F. microcarpa* and *D. regia* in the zoo garden may be due to the planting of these species to

Table 4. The dominant tree species in whole Giza Zoo's garden based on importance value index (IVI) exceeding 1.0 and their abundance (A), relative abundance (RA), relative species density (RD_i) and relative species dominance (RD_o).

Species	IVI	A	RD_i (%)	RD_o (%)
Ficus microcarpa L.fil.(syn. *F. nitida*)	18.80	460	25.76	11.84
Delonix regia (Bojer ex Hook) Raf.	18.73	400	22.40	15.07
Ficus religiosa L.	5.41	35	1.96	8.87
Eucalyptus camaldulensis Dehnh.	4.54	41	2.30	6.79
Ceiba speciosa (A.St.-Hil., A.Juss. & Cambess.) Ravenna (syn. *Chorisia speciosa*)	2.46	31	1.74	3.19
Tipuana tipu (Benth.) Kuntze	2.08	28	1.57	2.59
Bombax ceiba L. (syn. *B. malabaricum*)	2.03	20	1.12	2.95
Ficus benghalensis L.	1.85	4	0.22	3.49
Khaya senegalensis (Desv.) A.Juss.	1.67	16	0.90	2.45
Ficus spp. (Aknown)	1.63	15	0.84	2.42
Terminalia arjuna (Roxb.) Wight & Arn.	1.33	21	1.18	1.48
Ficus virens W.T.Aiton (syn. *F. infectoria*)	1.22	10	0.56	1.88
Swietenia mahagoni (L.) Lam.	1.22	17	0.95	1.49
Casuarina equisetifolia L.	1.20	19	1.06	1.33
Ficus elastica Roxb. ex Hornem.	1.20	11	0.62	1.78
Mangifera indica L.	1.15	18	1.01	1.29
Morus alba L.	1.03	30	1.68	0.38

secure shade for visitors. This observation confirmed the works of Martins, (1991) who concluded that RD_i and RD_o in isolated forms, reveal essential aspects for the characterization of the garden entity but do not indicate the structure of the floristic vegetation as a whole. Therefore, the IVI has been a great parameter to split different types of species and to link them to environmental or abiotic factors. Also, Netto *et al*., (2015) reported that the IVI is the parameter for ranking species in a spatial context of a tree population

Table (5) shows that section 1 has the higher abundance value (762) followed by section 3 and then section 2 with 560 and 451 individuals, respectively. The more species existing in a section the 'richer' the area. Therefore, S3 is the richer section in the garden with 146 woody species. This analysis is reflected on the Shannon-Wiener (H'), species richness (Chao 1) and var (S_{Chao1}) where section 3 is the most diverse one in the garden with 0.10, 10.47 and 22.91, for the former indices respectively. The little individual number and giant singletons species are significant factors that may have caused an increase in diversity richness in section 3 in comparison to other sections. Also, the tree evenness is significantly higher in sections 3 and 2 by 32.1 and 33.9%., respectively compared with section 1. This result matches with Heip *et al*. (1998), who concluded that diversity indices describe the community structure and reflect the effective number of species with equivalent diversity and indicate ecosystem function.

Singletons mean the number of species that are represented by one individual. Likewise, doubletons mean the number of species represented by two individuals, then tripletons mean the number of species represented by three individuals. Therefore, these three categories indicate rare species. The garden comprises 90 singletons species, most of them located in section 3 (80 species) followed by sections 2 and 1 with 32 and 27 species, respectively. Likewise, the garden as a whole comprises 26 doubletons and 17 tripletons species, and the majority are in section 3 with 24 and 15 species, respectively (Table, 5). Shannon-Wiener diversity index was higher in section 3 (5.38) followed by sections 2 and 1 with 4.64 and 3.49, respectively. Table (5) reveals that the higher diversity in section 3 seems to originate from a greater abundance of dominant, recedent and subrecedent species (50, 94 and 212,

Table 5. The diversity measures of woody taxa species distributed on the three sections and the whole garden of Giza Zoo botanic garden.

Parameters	S1	S2	S3	Whole garden
Number of species (species richness)	77	79	146	201
Number of specimens (abundance)	762	451	560	1773
Eudominant species* 10 % ≤ Di ≤ 100 %	2	1	1	2
Dominant species 5 % ≤ Di < 10 %	0	0	1	0
Subdominant species 2 % ≤ Di < 5 %	1	11	3	2
Recedent species, 1 % ≤ Di < 2 %	7	7	13	10
Subrecedent species 0 % < Di < 1 %	66	60	128	187
Abundance of eudominant species	500	150	160	860
Abundance of dominant species	0	0	50	0
Abundance of subdominant species	19	145	44	77
Abundance of recedent species	84	50	94	232
Abundance for subrecedent species	159	106	212	604
Singletons (species with 1 individual)	27	32	80	90
Doubletons (species with 2 individuals)	19	12	24	26
Tripletons (species with 3 individuals)	5	14	15	17
Shannon-Wiener diversity index (H')	3.49	4.64	5.38	4.93
Evenness	0.56	0.74	0.75	0.64
Species richness estimator (Chao 1)	4.40	8.08	10.47	356.77
Var (S_{Chao1})	11.30	12.76	22.91	2167.40

*** Tischler's scale for species dominance**

respectively). The Evenness index varied from 0 to 1. It is equivalent to 1 when all species have the same abundance (tree numbers) and tend towards zero when the total of flora is concentrated on only one species. Although S3 and S2 nearly had the same evenness (0.75 and 0.74, respectively) but S3 had the higher species richness as a result that S3 has a higher number of singleton, doubleton and tripleton by 80, 24 and 15 species, respectively.

The data reveals that *Ficus microcarpa* and *Delonix regia* are the Eudominant species by 39.2 and 26.1%, respectively in section 1 and *Delonix regia* (33.4%) in section 2 then, *Ficus microcarpa* in section 3 by 28.7%. Moreover, *Ficus microcarpa* represent the only Dominant species in section 3. In section 1, *Morus alba* is representing Subdominant species followed by *Eucalyptus camaldulensis, Ficus religiosa, Khaya senegalensis, Mangifera indica, Syzygium cumini, Taxodium distichum, Tipuana tipu* as the Recedent species then, 66 species as Subrecedent. Likewise, section 2 has 11 species (*Ceiba speciosa, Terminalia arjuna, Enterolobium # contortisiliquum, Casuarina equisetifolia, Platycladus orientalis, Tipuana tipu, Terminalia bellirica, Bauhinia variegata, Eucalyptus camaldulensis, Ficus religiosa and Swietenia mahagoni*) as Subdominant followed by 7 species (*Dalbergia sissoo, Bombax ceiba, Morus alba, Peltophorum africanum, Casuarina cunninghamiana, Brachychiton rupestris* and *Ficus saussureana*) as Recedent then, 60 species as Subrecedent. As well, section 3 has 3 species (*Eucalyptus camaldulensis, Enterolobium #ontortisiliquum* and *Ailanthus altissima*) as Subdominant followed by 13 species (*Ficus religiosa,Bombax ceiba, Ceiba* *crispiflora, Ficus spp., Alstonia scholaris, Ceiba speciosa,Swietenia mahagoni, Tipuana tipu, Brachychiton australis, Ficus elastic, Joannesia princeps,Millingtonia hortensis* and *Toona ciliata*) as Recedent then, 128 species as Subrecedent.

Similarity:

Jaccard and Sorensen indices give a very good idea of the presence or absence of species between two sections of the garden with qualitative data as species lists. It is based on the idea that the more species the two sections have in common, the more similar they are. Therefore, Table (6), revealed that the values of the coefficient of similarity vary from 25% to 38.5% for the index of Jaccard and from 31% to 54% for the index of Renkonen. The lowest Jaccard index value was obtained between S1-S3 (23%). The highest value was noted between S1-S2 (38.5%). According to Muller and Ellenberg (1974) and Chao *et al*. (2006), populations having less than 65% similarities are regarded as dissimilar. The low similarity of the three sections of Giza Zoo, maybe because they have limited areas and are composed of a large number of species.

Threatened species:

Addressing threats in managed ecosystems such as botanic gardens is essential. A better understanding of the distribution of woody taxa in the botanic garden will support the development and implementation of suitable plans to address the distribution inequality of these taxa in the garden sections and consequently reducing this problem.

The survey of threat trees in Giza Zoo garden has recorded that 145 individual trees belonging to 18 species are either endangered, near threatened or vulnerable according to the IUCN red list of threatened species (IUCN, 2021). Table (7) revealed that the *Pterocarpus indicus*, a (lonely individual) and *Ceiba crispiflora* population (10 individuals) have been globally listed as endangered (Barstow, 2018 and Fernandez *et al*., 2020) therefore, may possibly likely be the last remaining of these species in Egypt and may also represent the last chance to guarantee their survival. Amongst these threatened species, also *Aegle marmelos* has most recently been assessed for The IUCN red list of threatened species in 2019 and is listed as near threatened (Plummer, 2020). Unfortunately, the global population trend is decreasing. One of the most unexpected things is that *Eucalyptus camaldulensis* (river red gum) has been assessed as near threatened (Fensham *et al*., 2019) although, it grows on the rural roads and fields across the Nile delta as a riparian tree. Fortunately, the Giza Zoo garden has huge trees of good status (41 individuals) of river red gum distributed in the three sections of the garden (Table, 7). Interestingly, the closest relative of the river red gum tree is *Eucalyptus robusta,* another near-threatened species, (Fensham *et al*., 2019) that only identified through two individuals, in sections 1 and 3. Likewise, 19 individuals of *Platycladus orientalis*, a conifer species that are identified as near-threatened, have been distributed in the three sections of the garden as shown in Table (7). The few individuals of *Cedrela odorata* (2 and 1 trees) in section 1 and section 3, respectively assessed for the IUCN red list in 2017 and are listed as vulnerable (Mark and Rivers, 2017). Globally, their population trend is decreasing. Also, the iconic individual of *Saraca asoca* standing in section 1 and the two individual trees of *Terminalia benzoin* located in section 3 have been identified globally as vulnerable in the red list of threatened species (CAMP, 1998 and Page, 1998). Moreover, section 3 in the garden has only two vulnerable specimens of *Eucalyptus gomphocephala*, which its global population trend is decreasing, and *Macadamia integrifolia* (Fensham *et al*., 2019 and Forster *et al*., 2020). *Khaya grandifoliola, Khaya senegalensis, Swietenia macrophylla* and *Swietenia mahagoni*, members of Meliaceae family, are assessed as vulnerable (Hawthorne, 1998; World Conservation Monitoring Centre, 1998b; World Conservation Monitoring Centre, 1998c and Barstow, 2020). Although the garden has a

Table 6. Jaccard's and Renkonen similarity indices among three sections of Giza Zoo garden.

Jaccard's similarity index	**Section 2**	**Section 3**
Section 1	0.384	0.233
Section 2		0.250
Renkonen index		
Section 1	0.471	0.542
Section 2		0.308

Table 7. Threatened species distributed in the three sections of Giza Zoo garden with their threatened category and the world population trend according to the IUCN red list of threatened species, 2021.

Species	Number of individuals Section No.			Threatened category	World Population trend	Reference
	S1	S2	S3			
Aegle marmelos	1	-	1	near threatened	decreasing	Plummer, 2020
Araucaria heterophylla	2	2	2	vulnerable	increasing	Thomas, 2011
Cedrela odorata	2	-	1	vulnerable	decreasing	Mark, and Rivers, 2017
Ceiba crispiflora	1	-	9	endangered	decreasing	Fernandez *et al.,* 2020
Eucalyptus camaldulensis	14	10	17	near threatened	stable	Fensham *et al*., 2019
Eucalyptus gomphocephala	-	-	1	vulnerable	decreasing	Fensham *et al*., 2019
Eucalyptus robusta	1	-	1	near threatened	decreasing	Fensham *et al*., 2019
Jacaranda mimosifolia	5	3	2	vulnerable		Hills, 2020
Joannesia princeps	1	1	6	vulnerable		World Conservation Monitoring Centre, 1998a
Khaya grandifoliola	-	-	1	vulnerable		Hawthorne, 1998
Khaya senegalensis	12	3	1	vulnerable		World Conservation Monitoring Centre, 1998b
Macadamia integrifolia	-	-	1	vulnerable		Forster *et al*., 2020
Platycladus orientalis	5	12	2	near threatened		Farjon, 2013
Pterocarpus indicus	1	-	-	endangered	decreasing	Barstow, 2018
Saraca asoca	1	-	-	vulnerable		CAMP, 1998
Swietenia macrophylla	2	-	3	vulnerable		World Conservation Monitoring Centre, 1998c
Swietenia mahagoni	-	10	7	vulnerable	decreasing	Barstow, 2020
Terminalia bentzoe	-	-	2	vulnerable		Page, 1998

lonely specimen of *Khaya grandifoliola* in section 3, there are numerous individuals of the other three species (16, 5 and 17, respectively). The good planning and scientific vision of the garden administration led to having numerous specimens of *Araucaria heterophylla, Jacaranda mimosifolia and Joannesia princeps* which were assessed as vulnerable (Thomas, 2011; Hills, 2020 and World Conservation Monitoring Centre, 1998a), with 6, 10 and 8 individuals, respectively distributed on the three sections of the garden.

It is known that increasing the area of impervious surfaces effectively isolates much of the underground soil and prevents precipitation from penetrating into the soil then, increases water stress on urban forests. Also, Morgenroth *et al*. (2013) stated that tree growth is affected by different abiotic factors such as soil (moisture, volume, porosity, chemistry). A change in the availability of soil moisture and soil nutrients in the urban environment can result in costly damage to infrastructure whereas, tree roots proliferate in spots beneath impervious pathways and sidewalks that supply sufficient moisture and nutrients for root system survival and growth (D'Amato *et al.,* 2002). On the other hand, intensive human activities during the day and at night, especially on vacations and traditional celebrations, negatively drives species richness. This is because human disturbances on biodiversity result from overt or directed activities on biodiversity. This observation is proved in section A which covered the north gate and crisscrossing paths leading to the animal house. Studies by Nielsen *et al*., (2013); Alvey (2006) and Toth *et al*., (2009) also concluded that human activity plays a vital role in driving and defining the richness within green areas.

CONCLUSION

The Giza Zoo garden is an extraordinarily diverse hotspot with an unusually high number of woody taxa found nowhere else in Egypt especially, tropical species (Table, 8). A total of 1773 individual trees representing 202 species belonging to 50 families were identified in the three sections of the garden. Therefore, the garden plays a vital role in conserving 145 individuals as threatened trees belonging to 18 species that are either endangered, near threatened or vulnerable according to the IUCN red list of threatened species. Moraceae is the highest dominant family in Giza Zoo botanical garden with 605 individuals, followed by Fabaceae, Malvaceae, Myrtaceae, Meliaceae, Cupressaceae, Bignoniaceae, Combretaceae, Casuarinaceae, Anacardiaceae, Bombaceae, Euphorbiaceae, Sapindaceae, Sapotaceae, Simaroubaceae and Apocynaceae with 579, 88, 74, 57, 44, 43, 37, 26, 25, 25, 17, 15, 13, 12 and 11 individuals, respectively. Another 22 families were represented by 8-2 individuals and 10 families were represented by a lonely individual (Annonaceae, Araliaceae, Bixaceae, Loganiaceae, Lythraceae, Malpighiaceae, Phytolaccaceae, Platanaceae, Rubiaceae and Scrophulariaceae). The understory layer that ranges 6-20 m in height represents 73% of woody trees in the garden (1291 individuals). Also, 3% of the trees are more than 20 m in height (48 individuals) and represent the emergent layer besides 24% are less than 6m in height (434 individuals) and represent the suppressed layer. The tallest trees in section 1 and section 3 are represented by two species (*Eucalyptus camaldulensis* and *Ficus religiosa*, 30 m in height per each). The lonely tallest tree in section 2 is *F. religiosa* (30 m in height). On the other hand, 9 individuals only are more than 200 cm in dbh and 350 are less than 25cm in dbh then, 42 % of them ranged from 25-50 cm in dbh (749 individuals). The huge trees in section 1 and section 2 are *F. benghalensis* (308.3 and 300.0 cm dbh, respectively) whereas, the only huge one in section 3 is *F. religiosa* (238.8 cm dbh). The higher relative dominance (RD_o) was detected for *D. regia* (15.07%) followed by *F. microcarpa* (11.84%). Therefore, the higher IVI was recorded for *F. microcarpa* and *D. regia* with 18.80 and 18.73. The garden encloses 90 singletons species, most of them located in section 3 (80 species) followed by sections 2 and 1 with 32 and 27 species, respectively. Likewise, the garden as a whole comprises 26 doubletons and 17 tripletons species, and most are in section 3.#The abundance ranged from 451 to 777 trees/section with a mean of 598 (±165.3)/section. Moreover, the density ranged from 15.19 to 31.33 trees/feddan with a mean of 22.63 (±8.14) trees/feddan. Section 1 has the higher abundance value (762) followed by section 3 and then section 2 with 560 and 451 individuals, respectively. Conversely, section 3 is the richer one in the garden with 146 woody taxa species followed by section 2 and then, section 1. This is reflected on the Shannon-Wiener (H'), species richness estimator (Chao 1) and var (SChao1) diversity indices where section 3 is the richer diverse one in the garden with 5.38, 10.47 and 22.91, for the former indices respectively.

Table (8). List of woody taxa in Giza zoo, Egypt.

Singletons species

S1

- *Aegle marmelos* (L.) Corrêa
- *Albizia lebbeck* (L.) Benth.
- *Aleurites moluccanus* (L.) Willd.
- *Bixa orellana* L.
- *Casuarina cunninghamiana* Miq.
- *Ceiba crispiflora* (Kunth) Ravenna
- *Celtis occidentalis* L.
- *Erythrina variegata* L (syn. *E. indica*)
- *Eugenia supraaxillaris* Spring
- *Ficus altissima* Blume
- *Ficus auriculata* Lour.
- *Ficus binnendijkii* Miq.
- *Ficus lutea* Vahl
- *Ficus lyrata* Warb.
- *Ficus sycomorus* L.
- *Harpullia arborea* (Blanco) Radlk.
- *Joannesia princeps* Vell.
- *Lagunaria patersonia* (Andrews) G.Don
- *Leucaena leucocephala* (Lam.) Dewit
- *Maclura pomifera* (Raf. ex Sarg.) C.K.Schneid.
- *Peltophorum africanum* Sond.
- *Pinus pinea* L.
- *Pterocarpus indicus* R.Vig.
- *Pterospermum acerifolium* Benth.
- *Saraca asoca* (Roxb.) J.J.de Wilde
- *Schefflera actinophylla* (Endl.) Harms
- *Tamarix nilotica* (Ehrenb.) Bunge
- *Vitex agnus-castus* L.

S2

- *Acacia arabica var. nilotica* (L.) Benth. (syn. *Vachellia nilotica* (L.) P.J.H.Hurter & Mabb.)
- *Albizia lebbeck* (L.) Benth.
- *Aleurites moluccanus* (L.) Willd.
- *Cassia fistula* L.
- *Cassia roxburghii* DC.
- *Cercis chinensis* Bunge
- *Chrysophyllum cainito* L.
- *Citharexylum spinosum* L. (syn. *Citharexylum quadrangulare*)
- *Dalbergia lanceolaria* subsp. *Paniculata* (Roxb.) Thoth. (syn. *D. paniculata*)
- *Ficus afzelii* G.Don
- *Ficus platyphylla* Delile
- *Fraxinus velutina* Torr.
- *Haematoxylon campechianum* L.
- *Harpullia pendula* Planch.
- *Jatropha curcas* L.
- *Joannesia princeps* Vell.
- *Leucaena leucocephala* (Lam.) Dewit
- *Libidibia ferrea* (Mart. ex Tul.) L.P.Queiroz (syn. *Caesalpinia ferrae*)
- *Magnolia grandiflora* L.
- *Moringa oleifera* Lam.
- *Parkinsonia aculeata* L.
- *Pinus pinea* L.
- *Prunus armeniaca* L.
- *Pterospermum acerifolium* Benth.
- *Putranjiva roxburghii* Wall.
- *Ricinus communis* L.
- *Robinia pseudoacacia* L.
- *Sideroxylon persimile* (Hemsl.) T.D.Penn.
- *Sophora tomentosa* L.
- *Spathodea campanulata* Beauv.
- *Tamarindus indica* L.
- *Tamarix nilotica* (Ehrenb.) Bunge
- *Ziziphus spina- christi* (L.) Willd

Singletons species of S3

- *Adenanthera pavonina* L.
- *Acer negundo* L.
- *Acokanthera oblongifolia* (Hochst.) Codd
- *Acrocarpus fraxinifolius* Wight & Arn.
- *Aegle marmelos* (L.) Corrêa
- *Albizia anthelmintica* (A.Rich.) Brongn.
- *Albizia lebbeck* (L.) Benth.
- *Albizia niopoides* (Spruce ex Benth.) Burkart
- *Albizia procera* (Roxb.) Benth.
- *Annona squamosa* L.
- *Antidesma bunius* (L.) Spreng.
- *Azadirachta indica* A.Juss.

Continued

- *Bischofia javanica* Blume
- *Bolusanthus speciosus* (Bolus) Harms (syn. *Lonchocarpus speciosus*)
- *Buddleja ×hybrida* Forq.
- *Cassia moschata* Benth.
- *Cassia roxburghii* DC.
- *Cedrela odorata* Vell.
- *Celtis occidentalis* L.
- *Cinnamomum verum* J.Presl (syn. *C. zeylanicum*)
- *Citharexylum spinosum* L. (syn. *Citharexylum quadrangulare*)
- *Colvillea racemosa* Bojer
- *Cordia africana* Lam. (syn. *C. holstii*)
- *Cordia macleodii* Hook.fil. & Thomson
- *Cordia myxa* Forssk
- *Cupressus sempervirens* L.
- *Dalbergia lanceolaria* subsp. *paniculata* (syn. *D. paniculata*)
- *Dalbergia sissoo* Roxb.
- *Eucalyptus gomphocephala* A.Cunn.
- *Eucalyptus robusta* Sm.
- *Faidherbia albida* (Delile*)* A.Chev. (syn. *Acacia albida*)
- *Feronia limonia* (L.) Swingle (syn. *Limonia acidissima*)
- *Flacourtia indica* (Burm.fil.) Merr.
- *Fraxinus angustifolia* Reut.
- *Fraxinus velutina* Torr.
- *Glycosmis pentaphylla* (Retz.) Corrêa
- *Gmelina arborea* Roxb. ex Sm.
- *Harpullia arborea* (Blanco) Radlk.
- *Hiptage benghalensis* (L.) Kurz
- *Holoptelea integrifolia* (Roxb.) Planch. (syn. *Ulumus integrifolia)*
- *Khaya grandifoliola* A.Juss. (syn. *K. dawei)*
- *Khaya senegalensis* (Desv.) A.Juss.
- *Lagerstroemia indica* L.
- *Leucaena leucocephala* (Lam.) Dewit
- *Macadamia integrifolia* Maiden & Betche
- *Manilkara hexandra* (Roxb.) Dubard
- *Melaleuca viminalis* (Gaertn.) Byrnes (syn. *Callistemon viminalis*)
- *Melia azedarach* L.
- *Mimusops elengi* L.
- *Moringa oleifera* Lam.
- *Nauclea orientalis* (L.) L.
- *Oroxylum indicum* (L.) Kurz
- *Pachira aquatica* Aubl.
- *Paraserianthes lophantha (Willd.) I.C.Nielsen* (syn. *Albizia lophantha*)
- *Phytolacca dioica* L.
- *Platanus occidentalis* L.
- *Populus alba* L.
- *Pseudobombax ellipticum* (Kunth) Dugand
- *Psidium guajava* L.
- *Pterygota alata* (Roxb.) R.Br. (syn. *Sterculia alata*)
- *Putranjiva roxburghii* Wall.
- *Rhamnus cathartica* L.
- *Salix babylonica* L.
- *Sapindus saponaria* L.
- *Senna siamea* (Lam.) H.S.Irwin & Barneby (syn. *Cassia siamea*)
- *Sesbania sesban* L.
- *Sideroxylon persimile* (Hemsl.) T.D.Penn.
- *Spondias lutea* L. (syn. *S. mombin*)
- *Sterculia foetida* L.
- *Strychnos nux-vomica* L.
- *Tabebuia aurea* Benth. & Hook.fil. ex S.Moore
- *Tecoma stans* (L.) Juss. ex Kunth
- *Terminalia arjuna* (Roxb.) Wight & Arn.
- *Terminalia catappa*
- *Ulmus parvifolia* Jacq.
- *Vitex agnus-castus* L.
- *Wisteria sinensis* (Sims) DC.
- *Wrightia arborea* (Dennst.) Mabb. (syn. *W. tomentosa*)

Doubletons species

S1

- *Araucaria heterophylla* (Salisb.) Franco (syn. *A. excelsa*)
- *Corymbia citriodora* (Hook.) K.D.Hill & L.A.S.Johnson (syn. *Eucalyptus citriodora*)
- *Ficus benghalensis* L.
- *Harpullia pendula* Planch.
- *Magnolia grandiflora* L.
- *Manilkara zapota* L. (syn. *Achras sapota*)
- *Melaleuca ericifolia* Sm.
- *Morus nigra* L.
- *Olea europaea* L.
- *Paulownia tomentosa* (Thunb.) Steud.
- *Pinus roxburghii* Sarg.
- *Psidium guajava* L.

S2

- *Araucaria bidwillii* Hook.
- *Araucaria heterophylla* (Salisb.) Franco (syn. *A. excelsa*)
- *Ficus benghalensis* L.
- *Inga dulcis* Mart. (syn. *Pithecellobium dulce*)
- *Millettia brandisiana* Kurz
- *Morus nigra* L.
- *Plumeria rubra* L.
- *Psidium guajava* L.
- *Pyrus calleryana* Decne.
- *Tecoma stans* (L.) Juss. ex Kunth
- *Toona ciliata* M.Roem. (syn. *Cedrela toona*)
- *Vitex agnus-castus* L.

Continued

- *Putranjiva roxburghii* Wall.
- *Swietenia macrophylla* G.King
- *Tectona grandis* L.f.
- *Toona ciliata* M.Roem. (syn. *Cedrela toona*)
- *Triadica sebifera* (L.) Small (syn. *Sapium sebiferum*)

Doubletons species of S3

- *Acacia arabica* var. *nilotica* (L.) Benth. (syn. *Vachellia nilotica* (L.) P.J.H.Hurter & Mabb.)
- *Acacia spp.*
- *Araucaria heterophylla* (Salisb.) Franco (syn. *A. excelsa*)
- *Butea monosperma* (Lam.) Kuntze (syn. *Butea frondosa*)
- *Cassia fistula* L.
- *Cedrela odorata* Vell.
- *Cordia alba* (Jacq.) Roem. & Schult.
- *Cordia sinensis* Lam.
- *Dillenia indica L.*
- *Erythrina variegata* L (syn. *E. indica*)
- *Ficus drupacea* Thunb.
- *Ficus lyrata* Warb.
- *Ficus sycomorus* L.
- *Grevillea robusta* A.Cunn.
- *Jacaranda mimosifolia* (syn. *J.acutifolia*)
- *Melaleuca ericifolia* Sm.
- *Myrcia leucadendra* St.-Lag.
- *Platycladus orientalis* (L.) Franco (syn. *Thuja orientalis*)
- *Prosopis juliflora* (Sw.) DC.
- *Pterospermum acerifolium* Benth.
- *Pyrus calleryana* Decne.
- *Schinus terebinthifolius* Raddi
- *Taxodium distichum* (L.) Rich.
- *Terminalia bentzoe* (L.) L.fil.
- *Terminalia chebula* Retz.
- *Ziziphus spina- christi* (L.) Willd

Tripletons species

S1

- *Bombax ceiba* L. (syn. *B. malabaricum*)
- *Dalbergia sissoo* Roxb.
- *Eriobotrya japonica* (Thunb.) Lindl.
- *Ficus platyphylla* Delile
- *Grevillea robusta* A.Cunn.
- *Spathodea campanulata* Beauv.

S2

- *Bolusanthus speciosus* (Bolus) Harms (syn. *Lonchocarpus speciosus*)
- *Brachychiton australis* (Schott & Endl.) *Terracino* (syn. *B. trichosiphon*)
- *Brachychiton discolor* F.Muell. (syn. *B. lurida*)
- *Cupressus sempervirens* L.
- *Erythrina variegata* L (syn. *E. indica*)
- *Ficus cunninghamii* (Miq.) Miq. (*F. benjamina*)
- *Jacaranda mimosifolia* D.Don (syn. *J.acutifolia*)
- *Khaya senegalensis* (Desv.) *A.Juss.*
- *Mangifera indica* L.
- *Pinus roxburghii* Sarg.
- *Radermachera ignea* (Kurz) Steenis (syn.*Mayodendron igneum*)
- *Syzygium cumini* (L.) Skeels (syn. *Eugenia jambolana*)
- *Taxodium distichum* (L.) Rich.

Tripletons species of S3

- *Aleurites moluccanus* (L.) Willd.
- *Amoora polystachya* Wall. (syn. *A. rohituka*)
- *Balanites aegyptiaca* (L.) Delile
- *Brachychiton rupestris* (Lindl.) Schum.
- *Casimiroa edulis* La Llave & Lex.
- *Cassia fistula* L.
- *Ceiba pentandra* (L.) Gaertn.
- *Chrysophyllum cainito* L.
- *Cinnamomum camphora* (L.) Nees & Eberm.
- *Manilkara zapota* (L.) P.Royen (syn. *Achras sapota*)
- *Markhamia lutea* (Benth.) K.Schum. (syn. *M. platycalyx*)
- *Millettia pinnata* (L.) Panigrahi (syn. *Pongamia pinnata*)
- *Morus alba* L.
- *Radermachera ignea* (syn.*Mayodendron igneum*)
- *Swietenia macrophylla* G.King

Therefore, we recommended the following:#

1. The garden could help in preventing the extinction of its trees such as *Araucaria heterophylla, Cedrela odorata, Ceiba crispiflora, Eucalyptus gomphocephala, Jacaranda mimosifolia, Joannesia princeps, Khaya grandifoliola, Khaya senegalensis, Macadamia integrifolia, Joannesia princeps, Khaya grandifoliola, Khaya senegalensis, Macadamia integrifolia, Pterocarpus indicus, Saraca asoca, Swietenia macrophylla, Swietenia mahagoni* and *Terminalia benzoin* through integrated conservation action mentioned by Wilcove (2010).
2. The Weak conservation procedures in the garden have led more individuals of species that are over-mature and over-aged to their demise therefore, it is feared that extinct from the garden. So, it's imperative to immediately restore these lost species in the garden and place their diversity on a pathway to recovery.
3. Given the immense value of Giza Zoo's existing tree population and its potential vulnerability to future challenges such as climate change and the urban heat island effect, therefore we warn against any change in the vital structure of the garden soil by adding additional facilities, or increasing the impermeable areas so that their surviving valuable tree wealth does not deteriorate.
4. We warn to increase the area of impermeable pathways that will increase the stresses upon the garden trees. These stresses often lead the root system to proliferate in areas that have more-favorable conditions for growth, but this situation will cause infrastructure damage and pavement uplift then finally, this damage will be costly.
5. We suggest technical support for the botanic garden as the experts of the Timber trees department will be essential for allowing this valuable garden to continue its work and expand its collections of critical but under-represented species.

Also, the inventory of tree species entity and structure in this study will assist as a guide tool for the administration of the garden to reach the Egyptian sustainable development goals by 2030 and the global goals by 2050.

REFERENCES

Alvey, A. (2006). Promoting and preserving biodiversity in the urban forest. Urban Forestry and Urban Greening, 5:195-201.

Aparecido, L.E.O.; Rolim, G.S.; Richetti J.; De Souza P.S.; and Johann J.A. (2016). Köppen, Thornthwaite and Camargo climate classifications for climatic zoning in the State of Paraná, Brazil Cienc. e Agrotecnologia, 40(4):405-417.

Bahnasy, M.I. and Khamis, M.H. (2019). Distribution pattern of trees diversity in Orman Botanical Garden. Middle East Journal of Agriculture Research, 8(1):1-11.

Barstow, M. (2018). *Pterocarpus indicus*. The IUCN Red List of Threatened Species. https://dx.doi.org/10.2305/IUCN.UK.2018-2.RLTS.T33241A2835450.en

Barstow, M. (2020). *Swietenia mahagoni*. The IUCN Red List of Threatened Species. https://dx.doi.org/10.2305/IUCN.UK.2020-1.RLTS.T32519A68104916.en

CAMP (1998). *Saraca asoca*. Workshops on Medicinal Plants, India, 1997, The IUCN Red List of Threatened Species. https://dx.doi.org/10.2305/IUCN.UK.1998.RLTS.T34623A9879360.en

CBD (2021). First draft of the post-2020 global biodiversity framework. UN Environment Programme, Convention on Biological Biodiversity, 12 p.

Chao, A.; Chazdon R.L.; Colwell, R.K. and Shen, T.J. (2006). Abundance-based similarity indices and their estimation when there are unseen species in samples. Biometrics, 62(2):361–371.

D'Amato, N.E.; Sydnor, T.D.; Knee, M.; Hunt, R. and Bishop, B. (2002). Which comes first, the root or the crack? J. of Arboriculture, 28:277-282.

Ducey, M.J. and Knapp, R.A. (2010). Rapid Assessment of Relative Density in Mixed-Species Stands of the Northeastern United States. Inter. J. of Forestry Res. https://doi.org/10.1155/2010/212068

Farjon, A. (2013). *Platycladus orientalis*. The IUCN Red List of Threatened Species. https://dx.doi.org/10.2305/IUCN.UK.2013-1.RLTS.T31305A2803944.en

Fensham, R.; Laffineur, B. and Collingwood, T. (2019). River Red Gum (*Eucalyptus camaldulensis*). The IUCN Red List of Threatened Species. https://dx.doi.org/10.2305/IUCN.UK.2019-3.RLTS.T61909812A61909824.en

Fensham, R.; Laffineur, B. and Collingwood, T. (2019). Swamp Mahogany (*Eucalyptus robusta*). The IUCN Red List of Threatened Species. https://dx.doi.org/10.2305/IUCN.UK.2019-3.RLTS.T61915765A61915774.en

Fensham, R.; Laffineur, B. and Collingwood, T. (2019). *Eucalyptus gomphocephala*. The IUCN Red List of Threatened Species. https://dx.doi.org/10.2305/IUCN.UK.2019-3.RLTS.T133375329A133375331.en

Fernandez, E.; León, M.L.V.; Amorim, E.; Wagner Ribeiro Júnior, J.; da Rosa, P.; Martinelli, G. and Ferreira, C. (2020). Paineira-crespa (*Ceiba crispiflora*). The IUCN Red List of Threatened Species. https://dx.doi.org/10.2305/IUCN.UK.2020-3.RLTS.T177837271A177837275.pt

Forster, P.; Griffith, S.; Ford, A. and Benwell, A. (2020). Macadamia Nut (*Macadamia integrifolia*). The IUCN Red List of Threatened Species. https://dx.doi.org/10.2305/IUCN.UK.2020-3.RLTS.T113180064A113310165.en

Hamdy, R.S.; Abd El-Ghani, M.M.; Youssef, T.L. and El-Sayed, M. (2007). The floristic composition of some historical botanical gardens in the metropolitan of Cairo, Egypt. African J. of Agric. Res., 2(11):610-648.

Hawthorne, W. (1998). African Mahogany (*Khaya grandifoliola*). The IUCN Red List of Threatened Species. https://dx.doi.org/10.2305/IUCN.UK.1998.RLTS.T32172A9684738.en

Heip, C.H.R.; Herman, P.M.J. and Soetaert, K. (1998). Indices of diversity and evenness. Oceanis, 24(4):61-87.

Hills, R. (2020). *Jacaranda mimosifolia*. The IUCN Red List of Threatened Species. https://dx.doi.org/10.2305/IUCN.UK.2020-3.RLTS.T32027A68135641.en

IUCN (2021). The IUCN Red List of Threatened Species. Version 2021-3. https://www.iucnredlist.org.

Mark, J. and Rivers, M.C. (2017). Spanish Cedar (*Cedrela odorata*). The IUCN Red List of Threatened Species. https://dx.doi.org/10.2305/IUCN.UK.2017-3.RLTS.T32292A68080590.en

Martins, F.R. (1991). Estrutura de uma floresta mesófila (Ed. in Portugal). Editora da Universidade Estadual de Campinas, SP, Brasil, 246 p.

Morgenroth, J.; Buchanb, G. and Scharenbrochc, B.C. (2013). Belowground effects of porous pavements-soil moisture and chemical properties. Ecological Engineering, 51:221-228.

Mounce, R.; Smith, P. and Brockington, S. (2017). Ex-situ conservation of plant diversity in the world's botanic gardens. Nature Plants, 3:795-802.

Netto, S.P.; Amaral, M.K. and Marcio, C. (2015). A new index for assessing the value of importance of species-VIS. Agrarian Sciences An. Acad. Bras. Ciênc., 87(4):2265-2279.

Nielsen, A.; van den Bosch, M.; Maruthaveeran, S. and van den Bosch, K. (2013). Species richness in urban parks and its drivers: A review of empirical evidence. Urban Ecosystems, 17: 305-327.

Page, W. (1998). *Terminalia benzoin* subsp. *benzoin*. The IUCN Red List of Threatened Species. https://dx.doi.org/10.2305/IUCN.UK.1998.RLTS.T30745A9575875.en

Pinheiro, M.Â.A.; Ragonezi, C.; Oliveira, M.C.; Reis, F.; Macedo, F.L.; Freitas, J.G.R.; Nóbrega, H. and Ganança, J.F.T. (2022). Anticipating the climate change impacts on Madeira's agriculture: The characterization and monitoring of a Vine agrosystem. Agronomy, 12(9):1-30. https://doi.org/10.3390/agronomy12092201

Plummer, J. (2020). Bael Tree (*Aegle marmelos*). The IUCN Red List of Threatened Species. https://dx.doi.org/10.2305/IUCN.UK.2020-3.RLTS.T156233789A156238207.en

POWO, (2022). Plants of the World Online. Facilitated by the Royal Botanic Gardens, Kew Published on the Internet; http://www.plantsoftheworldonline.org/

Thomas, P. (2011). Norfolk Island Pine (*Araucaria heterophylla*). The IUCN Red List of Threatened Species. https://dx.doi.org/10.2305/IUCN.UK.2011-2.RLTS.T30497A9548582.en

Toth, F.; Haight, G.; Snyder, A.; George, S.; Miller, R.; Gregory, S. and Skibbe, A. (2009). Reserve selection with minimum contiguous area restrictions: An application to open space protection planning in suburban Chicago. Biological Conservation, 142:1617-1627.

Wilcove, D.S. (2010). Endangered species management: the U.S. experience. *In*: Conservation biology for all, edited by N.J. Sodhi and P.R. Ehrlich, pp. 220-235.Oxford University Press, Oxford.

World Conservation Monitoring Centre (1998a). Boleira (*Joannesia princeps*). The IUCN Red List of Threatened Species. https://dx.doi.org/10.2305/IUCN.UK.1998.RLTS.T32981A9740608.en

World Conservation Monitoring Centre (1998c). Big Leaf Mahogany (*Swietenia macrophylla*). The IUCN Red List of Threatened Species. https://dx.doi.org/10.2305/IUCN.UK.1998.RLTS.T32293A9688025.en

World Conservation Monitoring Centre (1998b). African Mahogany (*Khaya senegalensis*). The IUCN Red List of Threatened Species. https://dx.doi.org/10.2305/IUCN.UK.1998.RLTS.T32171A9684583.en

تقييم التنوع البيولوجي ونهج الحفاظ على الأنواع الخشبية في حديقة حيوان الجيزة، مصر

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هذه هي الدراسة الأولى لقياس تنوع الأصناف الخشبية في حديقة حيوان الجيزة التي تعتبر نقطة ساخنة ذات تنوع غير عادي من الأصناف الخشبية التي لا توجد في أي مكان آخر في مصر خاصة الأنواع الاستوائية. أجريت هذه الدراسة على عدة مراحل هي الإعداد والجرد والتحليل والتقييم. تستخدم الدراسة طرقاً كمية لتقييم تنوع الأصناف الخشبية والأنواع المهددة التي يتم حفظها في الحديقة عبر أقسامها الرئيسية. لذلك ، تم تقدير ثراء الأنواع وقيمة مؤشرا التنوع شانون و سيمبسون. تم استخدام مؤشر قيمة أهمية الأنواع ، وهو مقياس لمدى سيطرة نوع ما في مجتمع معين ، وحالة الحفظ لتقييم إمكانات الحفظ للأشجار في الحديقة. وجدنا أن الحديقة تلعب دوراً حيوياً في الحفاظ على ١٤٥ نموذج كأشجار مهددة تنتمي إلى ١٨ نوع إما معرضة للخطر أو قريبة من التهديد أو معرضة للخطر وفقاً للقائمة الحمراء للاتحاد الدولي لحفظ الطبيعة. أدت إجراءات الحفظ الضعيفة في حديقة الحيوان إلى زوال المزيد من الأشجار من الأنواع التي تجاوزت مرحلة النضج وأصبحت مسنة ويُخشى أن تنقرض من الحديقة. لذلك ، من الضروري استعادة هذه الأنواع المفقودة على الفور. كما نحذر من زيادة مساحة

الممرات المبلطة وإنشاء المزيد من المباني التي ستزيد من الضغط على أشجار الحديقة. لذلك، نقترح دعماً تقنياً للحديقة النباتية حيث سيكون خبراء قسم الأشجار الخشبية ضروريين للسماح لهذه الحديقة القيمة بمواصلة عملها وزيادة حصيلتها من الأنواع الحرجة. أيضاً، سيساعد جرد كيان وهيكل أنواع الأشجار في هذه الدراسة كأداة إرشادية لإدارة الحديقة للوصول إلى أهداف التنمية المستدامة المصرية بحلول عام ٢٠٣٠ والأهداف العالمية بحلول عام ٢٠٥٠.