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Original Article

Floristic Composition and Species Diversity in Sunt Forest Reserve, Khartoum State, Central Sudan

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Abstract

The study investigates the weed species composition and diversity in the Sunt Forest Reserve, Khartoum State, Central Sudan. The floristic composition comprises 21 species from 18 genera and 11 families. The Leguminosae family is the most abundant, with five weed species, followed by Poaceae with four and Asteraceae with two. Tragus berteronianus (Poaceae) is the most significant species based on the Importance Value Index (IVI), with an IVI of 89.53%. Polygala erioptera (Polygalaceae) is the second most significant, with an IVI of 85.71%, followed by Rorippa indica (Brassicaceae) and Cyperus squarrosus (Cyperaceae) with IVIs of 80.44% and 72.32%, respectively. The Shannon-Weiner Diversity Index for the area was 4.206, while the Simpson's Index of Diversity (1 – D) was 0.05682. These values indicate a relatively high species diversity compared to other subtropical forests worldwide.

Keywords: Floristic composition, Species diversity, Weed species, Sunt Forest Reserve, Khartoum State, Central Sudan.

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Introduction

Sunt Forest Reserve, situated at the confluence of the White Nile and Blue Nile rivers in Khartoum, Sudan, spans approximately 164 hectares. This urban forest lies within a critical ecological zone, supporting both the local environment and urban population. It features diverse riverbank vegetation, predominantly Acacia nilotica "Sunt," which stabilizes riverbanks and provides habitat for numerous bird species. The forest is a crucial stopover for migratory birds traveling between Eurasia and Africa. Recognized for its environmental benefits, including microclimate regulation and serving as an educational and recreational site, Sunt Forest was declared a forest reserve in 1932 and a bird sanctuary in 1945. However, it faces challenges from urban development pressures. (1-3).

The forest hosts a diverse range of plant species, primarily comprising various trees typical of riverbank and floodplain environments. Common tree species include *Acacia nilotica ssp. nilotica* (Sunt or Gum Arabic tree) and *Faidherbia albida* (Apple-ring Acacia), among other Acacia species. These species are well-adapted to the seasonal flooding and dry periods of the Nile floodplains. Besides the dominant trees, the forest supports various shrubs, grasses, and herbaceous plants that contribute to its biodiversity. These understory plants are crucial for maintaining the forest's ecological functions, providing habitat and food for various wildlife species. (4,5).

The diversity of native flora is a vital component of terrestrial ecosystems, playing a crucial role in protecting environmental stability (6) and buffering against weather extremes while providing habitat for wildlife (7).

The present study focuses on:

1- Analyzing the floristic composition, including life forms, floristic categories, and vegetation types (habits).

2- Describing the community structure by estimating frequency, density, cover, abundance, and Importance Value Index (IVI).

3- Quantifying biodiversity within the community and explaining commonly used diversity indices: Shannon-Weiner Index, Simpson's Index, Menhinick's Index, Margalef's Richness Index, Dominance Index, Berger-Parker Dominance Index, Bugas and Gibson's Index, Equitability Index, and Gini coefficient.

Material and Methods

Study Area:

The research was conducted in the Sunt Forest Reserve, located between latitudes 16° and 15° N and longitudes 32° 51' and 32° 45' E. Khartoum city, situated at an average altitude of 382 meters above sea level, experiences minimum temperatures ranging from 8°C to 10°C (dropping to 5°C at night) and maximum temperatures from 23°C to 25°C. A brief transitional season with temperatures around 40°C occurs from mid-September to early January, characterized by dust storms during the shift from southwesterly to northeasterly winds. The climate is semi-arid, hot, and dry, with an average annual rainfall of 110-200 mm, divided into a 3-4 months rainy season and a dry season for the remaining months. The soil is predominantly clay with a pH of 7.8 (neutral to slightly alkaline). The organic matter content is 0.9, and the EC value is around 0.9 mmhos/cm. Sodium and potassium ion levels are 4.4 and 0.1 meq/L, respectively. The levels of exchangeable cations, calcium plus magnesium, are 28 meq/L, while extractable cations are 4.5 meq/L (8). The terrain is mostly flat with some areas of depression.

The study was conducted in the Sunt Forest Reserve from November 2019 to April 2021, during the active plant growth period when most species were expected to be present.

Plant Material and Data Collection:

For the survey, 12 plots of 20m x 20m (400 m^2) were randomly selected in the Sunt Forest Reserve. Plant material was collected for later identification and confirmation of scientific names by consulting the literature, including Andrews (9,10) and EL-Kamali (11). The collected plants were deposited in the Herbarium of the Botany Department, Faculty of Science and Technology, Omdurman Islamic University, Omdurman, Khartoum State, Central Sudan.

Floristic Composition:

Life Forms:

Life forms refer to the various categories into which living organisms are classified based on their structural characteristics, ecological roles, and evolutionary relationships. Life forms of species were determined based on the location of the regeneration buds and the shed parts during the unfavorable season. Raunkiaer's life form classification system is a pivotal framework in plant ecology, categorizing plants based on their adaptive strategies for surviving adverse seasons, particularly concerning the position of their perennating (surviving) buds (12-14):

Phanerophytes: Plants with perennating buds located more than 25 cm above the ground, including most trees and shrubs. The elevated position of the buds helps them survive by staying above ground-level threats like flooding or low-level fires. Chamaephytes: Plants with perennating buds located between the ground surface and 25 cm above it. This category includes many small shrubs and perennial herbs, with lower bud positions offering protection from harsh weather, such as cold winds or heat.

Cryptophytes (Geophytes): Plants with perennating buds below the soil surface or water, including plants with bulbs, tubers, rhizomes, or corms. Being underground protects these buds from climatic extremes and herbivory.

Therophytes: Annual plants that survive unfavorable seasons as seeds, completing their life cycle within one growing season. Seeds can endure extreme conditions that adult plants cannot, allowing the species to persist through adverse periods.

Floristic Categories:

Floristic categories classify plant species based on various criteria, including geographical distribution, ecological preferences, and evolutionary relationships. The floristic categories of the investigated species were assigned to global geographical groups according to Wickens (15) and Zohary (16).

Ecological Parameters:

To describe the community structure, the following ecological parameters were estimated (17,18): relative frequency, relative density, coverage value index, relative abundance, and Importance Value Index (IVI).

Floristic Diversity:

Diversity indices are mathematical measures used to quantify biodiversity within a community, considering both species richness and evenness. Here are explanations of some commonly used diversity indices (19-21):

Shannon-Wiener Index (H'): Measures diversity by considering both the number of species and the evenness of their abundances. Simpson's Index (D): Measures the probability that two individuals randomly selected from a sample will belong to the same species, focusing on species dominance. Simpson's Diversity Index (1 – D) ranges between 0 and 1, where 0 indicates no diversity (one species dominates) and 1 indicates infinite diversity.

Menhinick's Index (D_M): Measures species richness, adjusting the number of species by the total number of individuals. Margalef's Richness Index (D_Mg): Measures species richness, taking into account the number of species and the number of individuals.

Dominance Index (D): Measures the degree to which a single species dominates a community. Values range from 0 to 1, where a value close to 0 indicates no single species dominates (high diversity), and a value close to 1 indicates one species is highly dominant (low diversity).

Berger-Parker Dominance Index (d): Measures the proportional abundance of the most common species. A lower value indicates higher diversity, while a higher value indicates lower diversity. Bugas and Gibson's Index (Brillouin Index): Measures diversity when the sample size is known and includes all individuals. Higher values indicate higher diversity. This index is sensitive to sample size and is best used for complete counts rather than estimates.

Equitability Index (E): Measures how evenly individuals are distributed among the different species, derived from the Shannon-Wiener Diversity Index. Values range from 0 to 1, where 1 indicates perfect evenness and lower values indicate increasing dominance by one or more species. Gini Coefficient (G): Measures inequality in species abundances, calculated based on the Lorenz curve. Ranges from 0 to 1, where 0 indicates perfect equality (all species

have the same abundance) and 1 indicates maximum inequality (one species is overwhelmingly dominant). Lower values suggest higher diversity in ecological contexts.

Each index provides a unique perspective on community structure and diversity, helping ecologists understand different aspects of biodiversity and the factors influencing it.

Results and Discussion

Floristic Composition

This study identified twenty-one vascular plant species in Sunt Forest Reserve. The recorded taxa belonged to 18 genera across 11 plant families. Dicotyledonous families accounted for 64%, while monocotyledonous families represented 36%. The monocotyledonous families include Cyperaceae, Poaceae, Typhaceae, and Vahliaceae. Annual species comprised 67% (14 species), while perennials accounted for 33% (7 species).

The floristic analysis of the Sunt Forest Reserve revealed the presence of several plant families: Leguminosae (5 species), Poaceae (4 species), Asteraceae, Malvaceae, and Cyperaceae (2 species each), with Amaranthaceae, Brassicaceae, Euphorbiaceae, Polygalaceae, Typhaceae, and Vahliaceae each represented by one species.

Six life form categories were observed in the study. Therophytes were the most frequent, with 11 species (52%), followed by chamaephytes with 5 species (24%). There were two species of geophytes (10%), and one species each of subtropical (5%), nanophanerophytes (5%), and helophyte (5%).

The chorological analysis of the vegetation in Sunt Forest Reserve indicated that pantropical species were the most represented, with 4 taxa (19%), followed by tropical and Saharo-Arabian species, each with 3 species (14%). Cosmopolitan and Sudanian species each had two species (10%), while SA-SU, Palaeotropical, Sudano-Zambesian, Sahara-Sind, Saharo-Arabian + Tropical, Sudano-Zambian, and Sahara-Arabian + Sudano-Zambezian were each represented by one species (5%).

The most dominant families were Leguminosae and Poaceae, representing more than 40% of the floristic

composition. The dominance of these families is attributed to their efficient seed dispersal mechanisms, leading to high diversity and wide distribution. Twenty-nine percent of the families were represented by only one species: Amaranthaceae,Brassicaceae, Euphorbiaceae,Polygalaceae, Typhaceae, and Vahliaceae.

The plant species, their families, life forms, floristic category (chorology) and vegetation type (habit) encountered in study shown in Table 1.

Table 1: Plant species recorded with their families, life forms, floristic category and vegetation type

Family	**Plant species**	**Life forms**	**Floristic category**	**Vegetaion Type**
Amaranthaceae	*Amaranthus graecizan* L.	Therophyte	Cosmopolitan	Annual
Asteraceae	*Pulicaria crispa* (Cass.) Oliv. And Hiern	Chamaephyte	Saharo-Arabian + Sudanian	Annual
	Xanthium strumarium	Therophyte	Cosmopolitan	Annual
Brassicaceae	*Rorippa indica* (L.) Hiern	Subtropical	Tropical and subtropical	Annual
Cyperaceae	*Cyperus squarrosus*	Cryptophyte (Geophyte)	Saharo-Arabian	Annual
	Pycreus mundtii Cheron	Geophyte	Palaeotropical	Perennial
Euphorbiaceae	*Chrozophora plicata* (Vahl.) Spreng	Therophyte	Susanian	Perennial
Leguminosae	*Tephrosia vicioides*	Chamaephyte	Pantropical	Perennial
	Tephrosia cioides	NanoPhanerophyte	Pantropical	Perennial
	Tephrosia apollineae (Delile) DC.	Chamaephyte	Sudanian	Perennial
	Trigonella glabra ssp. *glabra*	Therophyte	Sudano-Zambizian +	Annual

			Saharo- Sind	
	Senna occidentalis (L.) Link	Chamaephyte	Pantropical	Perennial
Malvaceae	*Corchorus rilocularis*	Therophyte	Saharo-Arabian	Annual
	Corchorus fascicularis	Therophyte	Saharo-Arabian +Tropical	Annual
Poaceae	*Tragus berteronianus*	Therophyte	Sudano-Zambezian	Annual
	Tetrapogon cenchriformis (A.Rich.) Clayton	Therophyte	Saharo-Arabian +Sodano-Zambezian	Annual
	Urochloa deflexa (Schumach) H. Scholz.	Therophyte	Tropical	Annual
	Brachiaria eruciformis Sm. Griseb	Therophyte	Tropical	Annual
Polygalaceae	*Polygala erioptera* DC.	Chamaephyte	Tropical	Annual
Typhaceae	*Typha angustata*	Helophyte	Pantropical	Perennial
Vahliaceae	*Vahlia digyna* (Retz.)Kuntze	Therophyte	Saharo-Arabian	Annual

Ecological Parameters:

Percentage Frequency:

The study examined species frequency, finding that *Polygala erioptera* and *Tragus berteronianus* had the highest frequency (83.33%), followed by *Rorippa indica* (75%) (Table 2).

Table 2: Top Ten Species with the Highest Frequency in the Study Area

No	Plant species	Frequency %
1	*Polygala erioptera*	83.33
2	*Tragus berteronianus*	83.33

3	*Rorippa indica*	75
4	*Brachiaria eruciformis*	66.67
5	*Cyperus squarrosus*	66.67
6	*Pulicaria crispa*	66.67
7	*Tetrapogon cenchriformis*	66.67
8	*Typha angustata*	58.33
9	*Urochloa deflexa*	58.33
10	*Vahlia digyna*	58.33

Density:

The density of weeds in Plant Community 4 was highest for *Tragus berteronianus* (1.7), followed by *Rorippa indica* (2.33) and *Cyperus squarrosus* (2.25) (Table 3).

Table 3: The ten leading species with the highest relative density in the study area at Khartoum State, Central Sudan

No	Plant Species	Density
1	*Tragus berteronianus Schult.*	1.7
2	*Rorippa indica E*	2.33
3	*Cyperus squarrosus* L.	2.25
4	*Brachiaria eruciformis* (Sm.) Griseb.	1.42
5	*Urochloa deflexa* (Schumach.) H. Scholz.	1.25
6	*Polygala erioptera* DC	1.08
7	*Tephrosia vicioides Schltdl.*	1.17
8	*Vahlia digyna (Retz.) Kuntze*	1.5
9	*Tephrosia apolinea*	1.0
10	*Tephrosia cioides*	1.0

Cover:

The highest weed cover in the Sunt Forest sub-region was recorded for *Rorippa indica* (52), followed by *Corchorus trilocularis* (50) and *Brachiaria eruciformis* (Table 4).

Table 4: The ten species with the highest coverage value index of the study area at Khartoum State, Central Sudan

No	Plant Species	Cover
1	*Rorippa indica*	52.0
2	*Corchorus rilocularis* L.	50.0
23	*Brachiaria eruciformis* (Sm.) Griseb.	30.0
4	*Urochloa deflexa* (Schumach.) H. Scholz.	29.0
5	*Typha angustata* Bory & Chaub.	24.0
6	*Tetrapogon cenchriformis* (A.Rich.) Clayton	20.0
7	*Cyperus squarrosus* L.	19.0
8	*Vahlia digyna (Retz.) Kuntze*	18.0
9	*Xanthium strumarium* L.	18.0
10	*Chrozophora plicata* (Vahl) A. Juss. ex Spreng.	17.0

Abundance:

The highest weed abundance in the Sunt Forest sub-region was recorded for *Amaranthus graecizans* (4.5), followed by *Cyperus squarrosus* (3.4) and *Rorippa indica* (3.1) (Table 5).

Table 5: The ten leading species with the highest relative abundance of the study area at Khartoum State, Central Sudan

No	Plant Species	Abundance
1	*Amaranthus graecizans* ssp. *Thellungianus* (Nevski)Gusev.	4.5
2	*Cyperus squarrosus* L.	3.4
3	*Rorippa indica E*	3.11
4	*Vahlia digyna (Retz.) Kuntze*	2.57
5	*Tephrosia vicioides Schltdl.*	2.33
6	*Trigonella glabra Thunb.*	2.14
7	*Urochloa deflexa* (Schumach.) H. Scholz.	2.14
8	*Brachiaria eruciformis* (Sm.) Griseb.	2.13
9	*Tephrosia apolinea*	2
10	*Tephrosia cioides*	2

Importance Value Index (IVI):

The importance value index of weeds in Plant community was very high for *Tragus berteronianus* Schult.89.53 and *Polygala erioptera* DC 85.71, followed by *Rorippa indica* 80.44 (Table 6).

Table 6: The ten leading important species at Sunt forest reserve study area in descending order of its Importance Value Index (IVI)

No	Plant species	IVI
1	*Tragus berteronianus Schult.*	89.53
2	*Polygala erioptera* DC	85.71
3	*Rorippa indica*	80.44
4	*Cyperus squarrosus* L.	72.32
5	*Tetrapogon cenchriformis* (A.Rich.) Clayton	68.75
6	*Pulicaria crispa*	68.75
7	*Vahlia digyna (Retz.) Kuntze*	62.4
8	*Urochloa deflexa* (Schumach.) H. Scholz.	61.72
9	*Brachiaria eruciformis* (Sm.) Griseb.	60.13
10	*Typha angustata* Bory & Chaub.	60.13

Species Diversity

The Shannon-Wiener Index values indicate greater diversity, accounting for both species richness (total number of species) and evenness (distribution of individuals among species). These values typically range from 1.5 to 3.5 in most ecological studies, with higher values signifying a more diverse community. The Simpson Index also reflects greater diversity with higher values. The Menhinick Index measures species richness relative to the number of individuals sampled, and higher values indicate greater richness. This

index is particularly useful for comparing species richness between samples of different sizes. The Margalef Index, which adjusts for sample size using a logarithmic transformation, also indicates greater species richness with higher values, making it useful for comparing different samples (22-25).

Table 7: Computed values of diversity indices for study area at Khartoum State, Central Sudan

No	Index	Value
1	Shannon-Weiner Index	4.206
2	Simpson Index	0.05682
3	Menhinick Index	1.315
4	Margalef s Richness Index	3.609
5	Dominance Index	0.9432
6	Berger-Parker Dominance Index	0.1098
7	Bugas and Gibson s Index	0.8787
8	Equitability Index	0.9575
9	Gini Coefficient	0.276

Relationships Between Ecological Parameters and Diversity Indices

Understanding the relationship between ecological parameters (frequency, density, cover, and abundance) and diversity indices (Simpson's Diversity Index, Shannon-Wiener Index, etc.) is fundamental in ecological studies.

Frequency and Diversity Indices: Frequency indicates the distribution of species across sampling units. A higher frequency of many species generally suggests higher species richness and evenness, contributing to higher diversity indices.

Density and Diversity Indices: Density provides information on the number of individuals per unit area. High density of a few species may lower diversity

indices by indicating dominance, while an even density distribution among many species increases diversity indices.

Cover and Diversity Indices: Cover measures the proportion of area occupied by species. High cover by a single species suggests dominance and lowers diversity indices, while balanced cover among species increases indices like the Shannon-Wiener Index.

Abundance and Diversity Indices: Abundance refers to the total number of individuals of each species. High abundance of diverse species contributes positively to diversity indices, reflecting species richness and evenness.

Importance Value Index (IVI) and Diversity Indices: IVI combines frequency, density, and cover to give a composite measure of species importance. High IVI values for several species usually correlate with higher diversity indices, indicating balanced species contributions to the community (21).

Integration of Ecological Parameters with Diversity Indices

Combining ecological parameters provides a more complete understanding of community structure. For example, while frequency and abundance give a picture of species presence and population size, cover and density offer insights into spatial distribution and dominance, respectively. Together, these parameters help calculate accurate diversity indices that reflect both species richness (number of species) and evenness (distribution of individuals among species) (26-28).

Conclusion

This study demonstrates that the plant species in the Sunt Forest Reserve interact successfully and coexist healthily within the ecosystem, as evidenced by the high species diversity observed. High species diversity indicates a stable ecosystem with a substantial number of successful species. The plant diversity in the Sunt Forest Reserve was highly compared to many other regions in Sudan. By integrating ecological parameters and floristic composition, ecologists can better understand and quantify biodiversity, leading to more informed conservation and management decisions. Further studies were recommended on plant

dispersal, crop-plant associations, and weed-tree plant associations.

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