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Horizontal Distribution Pattern: A Phorophyte Dependant Spatial Trend of Epiphytic Fern in a Greenbelt Corridor Using Geospatial Techniques

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Abstract

Arboreal epiphytic ferns are autotrophic and non-parasitic plant groups that grow or live on other plants, more especially the trees, without affecting their host and are the second most diverse tropical plants known to man. The study was aimed at assessing the spatial trend of horizontal distribution pattern of phorophyte dependant epiphytes using geospatial techniques, The ecological assessment of these epiphytic fern was carried out using an integrated ecological approach involving conventional method of Braun-Blanquet releve, Rapid Representative Epiphyte Diversity (RRED) Analysis and geospatial techniques using geospatial tool involving GPS (Dakota 10 model), GPS and ESRI's ARCMAP and Average Nearness Neighbour (ANN) analysis across the canopies of the phorophytes on both wings. The result revealed a total of 11 delineated sampled plots comprising phorophytes and non-phorophytes canopies. Six obligatory arboreal species (Phymatodes sclopendria, Platycerium bifurcatum, Pyrossia mechowii, Oleandra distenta, Nephrolepis pumicicola, and Drynaria laurentii were enumerated with their respective distribution pattern exemplified in Table 3.2. The phytosociology of the species has revealed the trend of frequency and density as exemplified in Table 3.4a, with P. bifurcatum and O. distenta recording the highest frequencies at the western and eastern wings of the green belt phorophytes, respectively. O. distenta had the highest density on both wings of green belt phorophytes. In conclusion, it has been shown that species with a clustered trend of distribution tend to have strong adaptive features, which possibly reflect their reproductive potential. Significantly, this work will aid ecological policies on biodiversity management and conservation of these species, which are risking extinction.

Keywords: *Phorophyte, Azadirachta indica, Phymatodes sclopendria, Platycerium bifurcatum, Nephrolepis pumicicola, Oleandra distenta, Pyrossia mechowii.*

1.0 INTRODUCTION

The inquiry in the study of arboreal epiphytic fern has proven to be the basis and foundation for comprehending the nature and biology of vascular plants, in light of their ecological importance in both tropical and temperate regions. And their ability to control the potential regeneration of forest ecosystems [1, 2, 3]. They are regarded as "Islands" that grow on tree canopies and are highly sensitive to forest disturbance and obstructions [4, 5]. They are mostly herbaceous in nature and with a substantial water storage capacity; thus tend to influence the hydrology and energy flow in phorophyte canopies [6,7]. The presence, growth, and development of these epiphytic ferns influence the uptake of carbon and biomass production while serving as a microhabitat, source of food and medicine, and tree canopy nutrient cycling [8, 9, 10]. Arboreal epiphytic ferns have a great influence on biodiversity because of their great significance in contributing to plant diversity, with about 25% of their vascular nature observed in tropical forests [11].

The horizontal distribution of arboreal epiphytic ferns entails the horizontal spread of epiphytic species across a given area; such distribution is irregular as a result of ecological and abiotic environmental (sunlight, precipitation, etc) gradients [12].

Though the complexity in epiphytic fern distribution lies in their degree of arboreal lifestyle dependence, their specialized tissues and organs, which make it possible for their adaptation [13]; their distribution pattern is influenced by the forest structure, which involves the phorophyte height and type, species distribution, epiphytic density, and disturbances such as tree felling [14, 11, 15, 16, 17]. It has been highlighted that the ecology of epiphytic ferns is poorly harnessed despite their importance in biodiversity protection [18]. Arboreal epiphytic ferns are known to be seen on different substrates, showing distinct and different responses to environmental and ecological factors [19]. Arboreal epiphytic ferns like the *Platycerium* species have shown one of the greatest microclimate functions in retaining and maintaining the amount of moisture in tree canopies [20] while serving as a cool buffering microhabitat to relatively hot and dry greenbelt canopies [21].

Greenbelt canopy, an aggregate of tree crowns of vegetation stand, is known for it habitation system, supporting diverse organisms ranging from insects to plant species, including arboreal epiphytic ferns [22].

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The use of randomness and deterministic approaches is highly crucial in the study of the canopies in rainforest communities [23]. The differences in the distribution of arboreal epiphytic ferns on a greenbelt canopy lie in the chance and limitations of their dispersal in different areas under different environmental gradients and canopy assemblages [19]. The phyto-social attributes of these epiphytic ferns have defined the greenbelt canopy as a hub to global biomass with the absolute ability to support numerous conditions that favour biodiversity [24].

It has been revealed that the complexity of elevation patterns, biotic and abiotic factors, is adversely affecting the various epiphytic fern phorophytes, and consequently generally posing difficulty in assessing their individual pattern of distribution, which informed the need for the adoption of geospatial tools [25]. Geospatial tools or Geographical Information Systems can be described as a hub for different geographical locations and maps of various abiotic and biotic indices, analyzing their combined attributes in order to produce a single result revealing their relationship [26]. The use and application of geospatial tools to understand the trends involved in the spatial distribution of epiphytic ferns within an ecological study area has also become one of the most recent approaches needed in the study of epiphytic fern biodiversity [27, 28]. This involves such tools as: the remote sensing, web-mapping, and GPS with its significant role to botanists, ecologists, and environmental managers as aid to the necessary information needed on the biodiversity of epiphytic fern [26].

Several studies have reported on epiphytic fern distribution with paucity of information as well as gaps in parts of Rivers State [28, 29, 30,31, 32, 33] and just about 4% of annual ecological publication on epiphytic fern distribution pattern [18]. Therefore, this study is aimed at assessing the horizontal distribution of arboreal epiphytic ferns with the objectives of identifying the presence of epiphytic ferns and their distribution trend using the Average Nearest Neighbor (ANN) analysis to predict the distribution pattern on both the western and eastern wing of the greenbelt canopy. Significantly, this study will reveal the rate at which ferns are distributed with the use of modern geospatial tools.

2.0 MATERIALS AND METHODS

2.1. Study Area and Field Sampling Delineation

The geographical location of the study area (Fig.2.1), with its neighborhood location and site has been documented [32]. The environmental characteristics involving the climatic conditions, vegetation system and the edaphic conditions have been described [34, 35, 36]. The survey and inventory were carried out on the gradient horizontal distribution of arboreal-fern bearing Phorophyte greenbelt canopy of the study site. A total stand of 214 trees (mainly *Azadirachta indica*) were observed from the inlet direction of Delta -Abuja campus gate of the study location sampled site. The sample site was delineated into eastern and western wing using a total distance of 1560m for the eastern wing, consisting of 145 canopy formations of which 69 trees are epiphytic-fern bearing Phorophytes while the western wing covers a distance of 1600m with 109 canopy formations in which 72 of them are epiphytic-fern bearing Phorophytes.

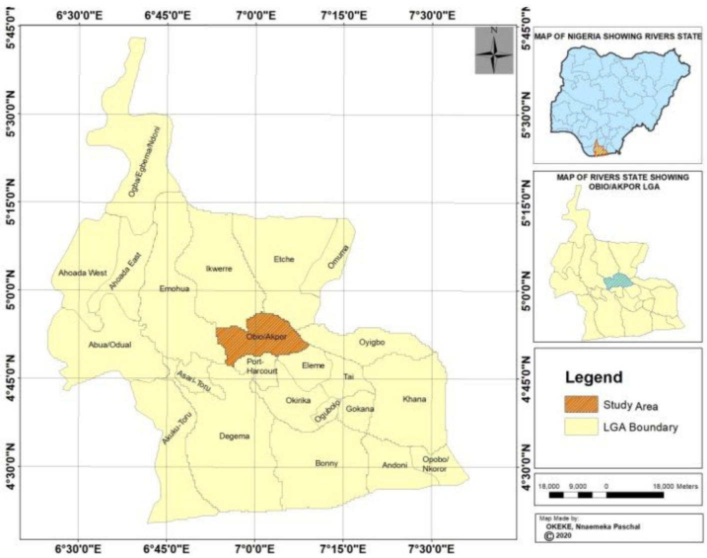


Fig. 2.1: Geographical situate of study area- Obio/Akpor

2.2 Sampling Methods, Procedure and Analysis

Using the line transect sampling design on the delineated eastern and western wing of the study sampled site, the Braun-Blanquet releve [37] and Rapid Representative of Epiphyte Diversity (RRED) [38] analytical methods were adapted. A total of 11 sampling plots were delineated on both the eastern and western wing. A handheld GPS (*BHnav 300 model*) was used to ascertain the geo-reference point of each tree Phorophyte along the horizontal row of the canopy gradients. The respective coordinates of all the Phorophytes and Non-Phorophytes tree stands and the obtained data were carefully inserted into the GIS ESRI's ARCMAP to generate the satellite imagery and maps of study location and sample site revealing the Phorophyte and Non-Phorophyte canopies with the qualitative trend condition of the epiphytic ferns (Fig.2.2).

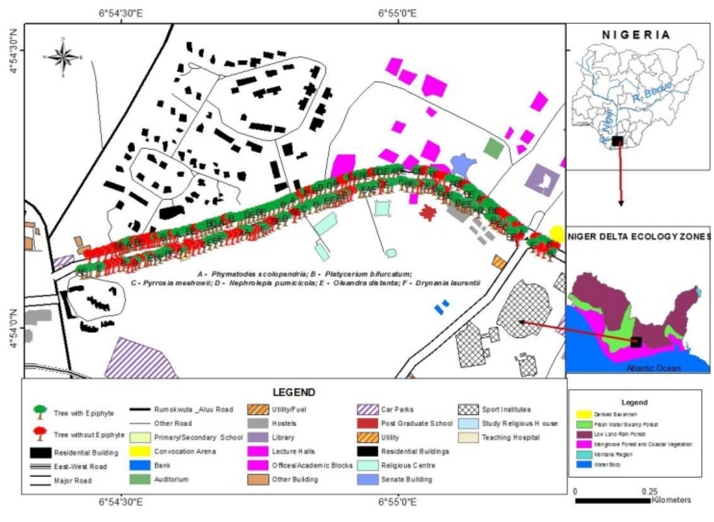


Fig. 2.2: Spatial trend of phorophyte and non-phorophyte canopies

2.3. Average Nearest Neighbor (ANN) Spatial and Phytosociological Analysis

The geo-referenced data obtained were imputed into the ArcGIS software, version 10.8 2021 for Nearest Neighborhood ratio between the western and eastern belt of the epiphytic canopies to ascertain the individual spatial distribution pattern between individual species of ferns on both belts.

A negative z-score indicates clustering, while a positive z-score means disperse or evenness. The z-score usually return a range value between -2.58 to 2.58. Therefore, a negative z-score less than -2.58 indicate a significant clustering at 0.01 probability level while a positive z-score greater than 2.58 indicates a significant regularity or dispersal at 0.01 probability level [39]. In addition, if the ratio is less than 1, it is said that the data exhibits a clustered pattern whereas a value greater than 1 indicates a dispersed pattern in the data [40]. The phytosociological analysis for frequency distribution of species and density of individual of a species as well as their relativity was based on Supriya and Yadava [41, 42] and Misra [43] methods.

3.0 RESULT

3.1. *Epiphytic Habit and Niche habitation*

The result of the Nearest Neighbor Analysis of the western and eastern belt has recorded six common obligatory arboreal epiphytic ferns under two families (Table 3.1), though with variation in their spatial horizontal distribution pattern (Table 3.2) in tandem with the variation of their various georeferenced situates (Tables 3.3a & b).

Table 3.1: Arboreal epiphytic ferns across the western and eastern greenbelt the study site

S/N	Species	Common name	Family	Epiphytic Habit / niche habitation
1	*Phymatodes sclopendria* Burm F.	Monarch fern	Polypodiaceae	Herbaceous obligate
2	*Platycerium bifurcatum* (Cav) C.Chr	Elkhorn fern	Polypodiaceae	Herbaceous obligate
3	*Pyrossia mechowii* Brause and Hieron	Pyrossia fern	Polypodiaceae	Herbaceous obligate
4	*Oleandra distenta* Kunze	Creeper fern	Davalliaceae	Herbaceous obligate
5	*Nephrolepis pumicicola* Baard	Macho fern	Davalliaceae	Herbaceous obligate
6	*Drynaria laurentii* (Christ) Hieron	Basket fern	Polypodiaceae	Herbaceous obligate

Table 3.2: Summary of Average Nearest Neighborhood Analysis

Fig	Species & Corridor Belt	Ratio	Z-Score	Distribution
1	*Nephrolepis*, Eastern Belt	3.139346	10.025073	Dispersed
2	*Nephrolepis*, Western Belt	1.583076	3.864084	Dispersed
3	*Oleandra*, Eastern Belt	0.410778	-7.645201	Clustered
4	*Oleandra*, Western Belt	0.617148	-4.746640	Clustered
5	*Phymatodes*, Eastern Belt	1.215316	1.541245	Random
6	*Phymatodes*, Western Belt	0.478777	-5.899142	Clustered
7	*Platycerium*, Eastern Belt	0.615303	-4.291307	Clustered
8	*Platycerium*, Western Belt	3.825287	37.446744	Dispersed
9	*Pyrossia*, Eastern Belt	2.873174	14.334050	Dispersed
10	*Pyrossia*, Western Belt	1.994663	4.661037	Dispersed

Table 3.3a: Eastern green belt georeferenced points, cryptogamic frequency and density of epiphytic phorophytes

EASTERN BELT											
Eastern plot Transect subunit	Lat. (N)	Long. (E)	*P. sclopendria* (a)	*P. bifurcatum* (b)	*P. mechowii* (c)	*N. pumicicola* (d)	*O. ditenta* (e)	*D. laurentii* (f)	Species notation per Phorophyte	Total population density (No of individual of species per phorophyte)	Species composition per subunit
P1	4.902270	6.920764	-	+	-	-	-	-	b		
	4.902601	6.920256	-	-	-	-	+	-	e	0.4	*P. bifurcatum*
	4.902715	6.920092	-	+	-	-	+	-	be	0.4	*P. mechowii*
	4.902963	6.919784	-	-	+	-	-	-	c	19.2	*O. distenta*
	4.903037	6.919651	-	-	-	-	+	-	e		
P2	4.903167	6.919478	-	+	-	-	-	-	b	25.6	*P. sclopendria*
	4.903258	6.919356	+	-	-	-	+	-	ae	2.2	*P. bifurcatum*
	4.903506	6.919044	+	+	-	-	-	-	ab	0.8	*N. pumicicola*
	4.903608	6.918821	+	+	-	-	-	-	ab	29.8	*O. distenta*
	4.903657	6.918767	-	-	-	-	+	-	e		
	4.903658	6.918694	+	-	-	+	+	-	ade		
	4.903687	6.918638	-	-	-	-	+	-	e		
P3	4.903703	6.918564	-	-	+	+	+	-	cde	0.2	*P. sclopendria*
	4.903748	6.918437	-	+	-	-	-	-	b	6.6	*P. bifurcatum*
	4.903847	6.918031	+	+	-	-	+	-	abe	1.8	*P. mechowii*
	4.903860	6.917956	-	+	-	-	+	-	be	2	*N. pumicicola*
	4.903873	6.917872	-	+	+	-	+	-	bce	62	*O. distenta*
	4.903885	6.917802	-	+	+	-	+	-	bce		
	4.903865	6.917610	-	-	-	-	+	-	e		
P4	4.903865	6.917534	-	+	-	-	-	-	b	6.8	*P. sclopendria*
	4.903852	6.917354	-	-	+	-	+	-	ce	6.8	*P. bifurcatum*
	4.903832	6.917216	+	+	+	-	+	-	abce	1.8	*P. mechowii*

	4.903835	6.917154	+	+	+	-	-	-	abce	40.4	*O. distenta*
	4.903817	6.917003	-	-	+	-	+	-	ce		
	4.903797	6.916853	-	+	-	-	+	-	be		
P5	4.903773	6.916690	-	-	+	-	-	-	c	0.2	*P. sclopendria*
	4.903752	6.916567	-	+	+	-	+	-	bce	1.2	*P. bifurcatum*
	4.903735	6.916494	-	-	-	+	+	-	de	1.6	*P. mechowii*
	4.903711	6.916408	-	-	+	-	+	-	ce	3.4	*N. pumicicola*
	4.903626	6.916092	-	+	-	-	+	-	be	18	*O. distenta*
	4.903596	6.915889	+	-	-	-	+	-	ae		
	4.903585	6.915841	-	-	-	-	+	-	e		
P6	4.903560	6.915774	-	+	+	-	+	-	bce		
	4.903375	6.915218	-	-	-	-	+	-	e	0.2	*P. bifurcatum*
	4.903353	6.915098	-	-	-	-	+	-	e	2.8	*P. mechowii*
	4.903318	6.914937	-	-	-	-	+	-	e	15.6	*O. distenta*
	4.903233	6.914741	-	-	-	-	+	-	e		
P7	4.903207	6.914673	-	-	-	-	+	-	e	10.2	*P. sclopendria*
	4.903140	6.914621	-	+	-	-	+	-	be	4	*P. bifurcatum*
	4.903152	6.914554	-	+	-	+	-	-	bd	0.2	*P. mechowii*
	4.903127	6.914489	-	+	-	-	-	-	b	18	*N. pumicicola*
	4.902995	6.914144	-	+	-	-	+	-	be	30.6	*O. distenta*
	4.902945	6.914015	-	-	+	-	-	-	c		
	4.902910	6.913955	+	-	-	-	+	-	ae		
	4.902615	6.913163	-	+	-	-	-	-	b		
P8	4.902581	6.913108	-	+	-	-	+	-	be	1.8	*P. sclopendria*
	4.902435	6.912764	-	-	-	-	+	-	e	1.4	*P. bifurcatum*
	4.902400	6.912669	-	+	-	-	+	-	be	18.4	*O. distenta*
	4.902273	6.912276	+	-	-	-	-	-	a		
	4.902225	6.912145	+	-	-	-	-	-	a		
P9	4.901936	6.911090	-	+	-	-	-	-	b	11.6	*P. sclopendria*
	4.901905	6.910958	-	-	-	-	+	-	e	0.6	*P. bifurcatum*
	4.901862	6.910673	-	-	+	-	-	-	c	0.4	*P. mechowii*
	4.901738	6.910195	-	-	-	+	-	-	de	144.8	*O. distenta*
	4.901638	6.909784	-	+	-	-	+	-	be		
	4.901624	6.909708	+	+	-	-	+	-	abe		
P10	4.901620	6.909637	-	+	-	-	+	-	be		
	4.901610	6.909558	-	-	-	-	+	-	e	1.2	*P. sclopendria*
	4.901536	6.990933	-	-	+	-	-	-	c	2	*P. bifurcatum*
	4.901521	6.909256	-	+	+	-	-	-	bc	5.8	*P. mechowii*
	4.901450	6.908909	+	+	-	-	-	-	ab	43	*O. distenta*
	4.901376	6.908524	-	+	-	-	-	-	b		
P11	4.901173	6.907846	-	-	-	-	+	-	e		
	4.901093	6.907578	+	+	-	-	+	-	abe	3.6	*P. sclopendria*
	4.901066	6.907523	-	+	-	+	+	-	bde	1.4	*P. bifurcatum*
	4.901013	6.907383	-	+	-	-	+	-	be	2.4	*N. pumicicola*
	4.900995	6.907318	+	-	-	-	+	-	ae	25.8	*O. distenta*

Table 3.3b: Western green belt georeferenced points, cryptogamic frequency and density of epiphytic phorophytes

WESTERN BELT											
Western plot Transect subunit	**Lat. (N)**	**Long. (E)**	***P. sclopendria* (a)**	***P. bifurcatum* (b)**	***P. mechowii* (c)**	***N. pumicicola* (d)**	***O. ditenta* (e)**	***D. laurentii* (f)**	**Species notation per Phorophyte**	**Estimated population density (No of individual species per phorophyte)**	**Species composition per subunit**
P1	4.901555	6.908717	-	+	-	-	+	-	be	3	*P. sclopendria*
	6.901618	6.908851	+	+	-	-	-	-	ab	8	*P. bifurcatum*
	4.901641	6.909023	+	-	-	-	-	-	a	17.6	*O. distenta*
	4.901666	6.909123	-	+	+	-	-	-	bc	0.2	*P. mechowii*
	4.901684	6.909210	+	+	-	-	-	-	ab		
	4.901723	6.909370	-	+	-	-	+	-	be		
P2	4.901907	6.910195	+	+	-	-	+	-	abe	10.4	*P. sclopendria*
	4.901958	6.910443	-	+	-	-	-	-	b	10.8	*P. bifurcatum*
	4.901970	6.910545	-	+	-	+	-	-	bd	0.2	*P. mechowii*
	4.901972	6.910624	+	+	-	-	+	-	abe	2.6	*N. pumicicola*
	4.902041	6.910822	+	-	-	+	+	-	ade	16.4	*O. distenta*
	4.902053	6.910893	+	-	-	-	-	-	a		
	4.902100	6.911075	-	+	+	-	-	-	bc		
	4.902096	6.911120	-	+	-	-	+	-	be		

P3	4.902141	6.911273	+	-	-	+	+	-	ade	22	*P. sclopendria*
	4.902141	6.911412	+	+	-	-	+	-	abe	4	*P. bifurcatum*
	4.902231	6.911614	-	+	+	-	-	-	bc	0.2	*P. mechowii*
	4.902286	6.911830	-	+	-	-	+	-	be	19.6	*N. pumicicola*
	4.902346	6.912902	+	+	-	-	-	-	ab	16.8	*O. distenta*
	4.902350	6.912079	-	+	-	+	-	-	bd		
P4	4.902381	6.912162	+	-	-	-	-	-	a	6.2	*P. sclopendria*
	4.902533	6.912499	-	+	-	-	-	-	b	3.6	*P. bifurcatum*
	4.902583	6.912638	+	+	-	-	-	-	ab	37.8	*D. laurentii*
	4.902636	6.912638	-	+	-	+	+	+	bdef	20.4	*N. pumicicola*
	4.902705	6.912988	+	-	-	-	+	-	ae	17.8	*O. distenta*
	4.902728	6.913015	-	+	-	-	+	-	be		
P5	4.902795	6.913207	-	-	-	+	+	-	de	29	*P. sclopendria*
	4.902874	6.913399	-	+	-	-	+	-	be	9	*P. bifurcatum*
	4.902926	6.913539	-	+	-	-	+	-	be	21.6	*N. pumicicola*
	4.902945	6.913609	+	+	-	-	+	-	abe	27.6	*O. distenta*
	4.903012	6.913819	+	+	-	+	+	-	abde		
	4.903022	6.913891	+	+	-	-	+	-	abe		
P6	4.903057	6.914010	+	+	-	-	+	-	abe	1.2	*P. sclopendria*
	4.903157	6.914281	-	+	-	-	-	-	b	26.2	*P. bifurcatum*
	4.903194	6.914348	+	-	-	-	+	-	ae	18.2	*O. distenta*
	4.903272	6.914475	+	+	-	-	+	-	abe		
	4.903288	6.914453	+	-	-	-	-	-	a		
	4.903403	6.914805	-	-	-	-	+	-	e		
P7	4.903507	6.915128	-	+	-	-	-	-	b		
	4.903519	6.915258	-	+	-	-	-	-	b	5.8	*P. bifurcatum*
	4.903585	6.915393	-	+	-	-	+	-	be	0.6	*N. pumicicola*
	4.903640	6.915499	-	-	-	+	-	-	d	3.2	*O. distenta*
	4.903700	6.915751	-	+	-	-	-	-	b		
P8	4.903765	6.916029	-	+	-	-	+	-	be	18.8	*P. sclopendria*
	4.903825	6.916231	-	-	+	-	+	-	ce	5	*P. bifurcatum*
	4.903868	6.916439	-	+	-	-	+	-	be	1.6	*P. mechowii*
	4.903900	6.916567	-	-	-	-	-	-		3.6	*N. pumicicola*
	4.903938	6.916684	+	+	-	-	+	-	abe	61	*O. distenta*
	4.903950	6.916828	+	+	-	-	+	-	abe		
	4.903977	6.917140	-	+	-	+	+	-	bde		
P9	4.903977	6.917218	+	-	-	-	-	-	a	15.2	*P. sclopendria*
	4.903985	6.917289	-	+	-	-	+	-	be	8.2	*P. bifurcatum*
	4.904007	6.917421	-	-	+	-	+	-	ce	0.6	*P. mechowii*
	4.904010	6.917649	-	-	-	+	-	-	d	3.4	*N. pumicicola*
	4.903970	6.918131	+	+	-	-	+	-	abe	32.4	*O. distenta*
	4.903921	6.918342	+	+	-	-	+	-	abe		
	4.903860	6918551	-	+	-	-	+	-	be		
P10	4.903816	6.918681	+	+	-	-	-	-	ab	102.6	*P. sclopendria*
	4.903790	6.918748	-	+	-	-	+	-	be	24.6	*P. bifurcatum*
	4.903737	6.918797	+	-	-	+	+	-	ade	0.6	*P. mechowii*
	4.903733	6.918874	+	-	-	-	-	-	a	29	*N. pumicicola*
	4.903702	6.918926	+	+	-	-	+	-	abe	123	*O. distenta*
	4.903642	6.919054	+	+	-	+	+	-	abde		
	4.903482	6.919291	+	+	-	-	+	-	abe		
	4.903432	6.919357	+	+	+	-	+	-	abce		
P11	4.903378	6.919391	-	+	-	-	-	-	b	8	*P. sclopendria*
	4.903330	6.919502	-	-	-	-	+	-	e	4.8	*P. bifurcatum*
	4.902880	6.920090	+	-	-	-	+	-	ae	42.4	*O. distenta*
	4.902845	6.920157	+	+	-	-	+	-	abe		
	4.902676	6.920389	+	-	-	-	-	-	a		

3.2. *Cryptogamic Phytosociology*

Frequency and Density

The phytosociological frequency of occurrence and density of observed cryptogams across the eastern and western green belt based on summary of phorophyte georeferenced points (Tables 3.4a&b), has recorded *Oleandra distenta* with the highest percentage frequency of 67.16% (Rf = 44.49%) followed by *Platycerium bifurcatum* with frequency of 50.75% (Rf = 33.62%) while *Drynaria laurentii* recorded 0% frequency at the eastern belt. *Platycerium bifurcatum* had the highest frequency of 70.59% (Rf = 33.82%) followed by *O. distenta* with 61.67% (Rf = 29.55%) while *Drynaria laurentii* recorded the least frequency of 1.47% (Rf = 0.70%)

The population of individual of each species (estimated density) (Table 3.4b), on the eastern belt recorded *Oleandra distenta* with the highest population density of 40.69 (Rd = 77.56%) and *Drynaria laurentii* with the least population density of 0.00 (Rd = 0.00%). The western belt recorded same species with the highest density of 34.22 (Rd = 44.56%), while *Pyrossia mechowii* recorded the least density of 0.31 (Rd = 0.40%).

Table 3.4a: Phytosociological summary result of frequency distribution of observed cryptogams across the green belt

S/N	Green Belt Percentage Frequency Distribution of Epiphyte				
	Species	Eastern belt	Western belt	Eastern %RF	Western %RF
1	*Phymatodes sclopendria*	0.22	48.53	0.15	23.25
2	*Platycerium bifurcatum*	50.75*	70.59**	33.62	33.82
3	*Pyrossia mechowii*	23.88	8.82	15.82	4.23
4	*Nephrolepis pumicicola*	8.96	17.65	5.94	8.46
5	*Oleandra distenta*	67.16**	61.67*	44.49	29.55
6	*Drynaria laurentii*	0.00	1.47	0.00	0.70
	TOTAL %F	**150.97**	**208.73**		

Table 3.4b: Phytosociological summary result of density of observed cryptogams across the green belt

S/N	Green Belt Population Density of Epiphyte				
	Species	Eastern belt	Western belt	Eastern %RD	Western %RD
1	*Phymatodes sclopendria*	5.56	19.67	10.60	25.61
2	*Platycerium bifurcatum*	2.44	10.00	4.65	13.02
3	*Pyrossia mechowii*	1.35	0.31*	2.57	0.40
4	*Nephrolepis pumicicola*	2.42	9.16	4.61	11.93
5	*Oleandra distenta*	40.69**	34.22**	77.56	44.56
6	*Drynaria laurentii*	0.00*	3.44	0.00	4.48
	TOTAL Density	**52.46**	**76.80**		

Distribution pattern

The phytosociological result based on the Average Nearest Neighbor (ANN) geospatial Analysis, revealed distribution pattern of the species based on distances between species within the respective corridor formation of the eastern and western greenbelt represented in Table 3.2.

Nephrolepis pumicicola

The ANN analysis of the eastern corridor green belt *N. pumcicola* with a coverage distance of 181.81m revealed a Nearest Neighbor Ratio index of 3.14 greater than 1 (the hypothetical random distribution index) (Fig 3.1) while the western belt *N. pumicicola* with distance of 62.25m had a Nearest Neighbor ratio index of 1.58 (Fig 3.2) greater than 1. This implies a dispersed trend of distribution and given a critical value (Z-score) of 10.03 (eastern belt) and 3.86 (western belt), there is a less than 1% likelihood that the dispersed pattern could be the result of random chance.

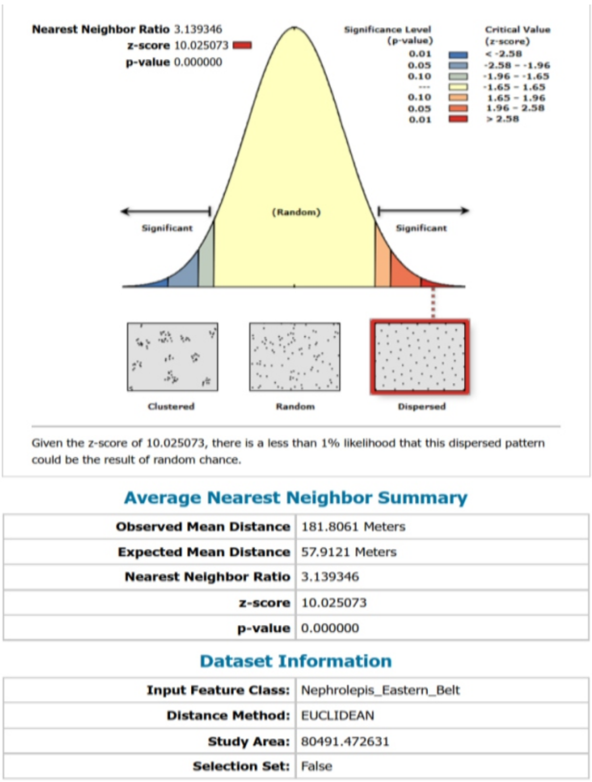


Fig 3.1. Nearest Neighborhood Analysis of eastern belt Nephrolepis pumicicola

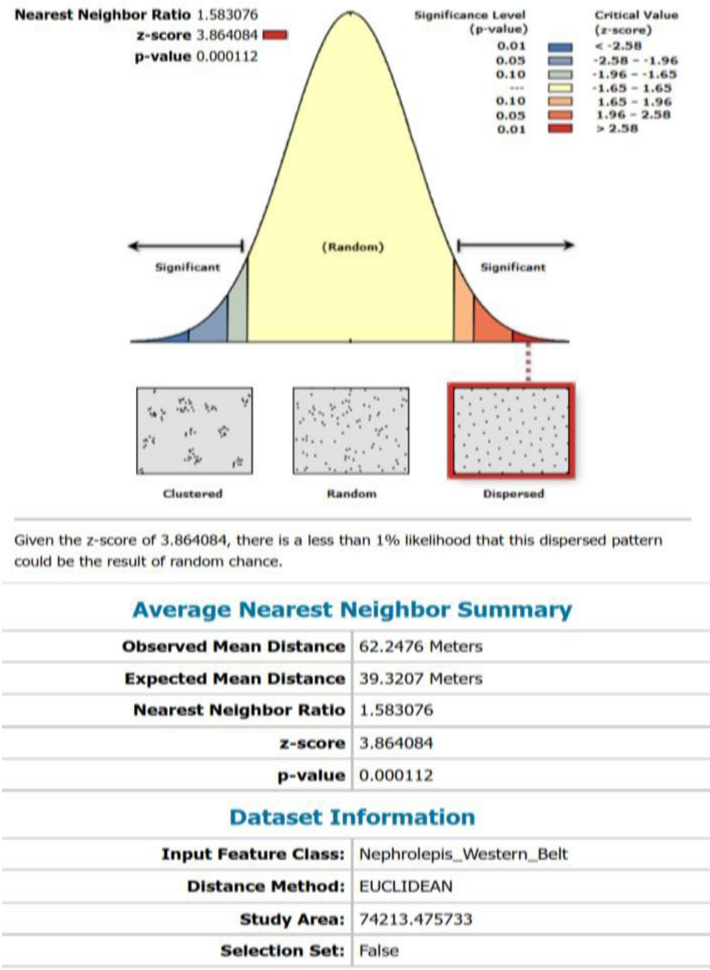
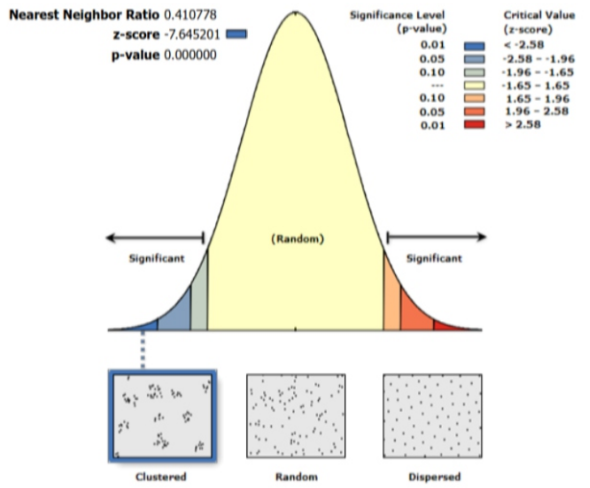


Fig 3.2. Nearest Neighborhood Analysis of western belt Nephrolepis pumicicola

Oleandra distenta

The *Oleandra distenta* of the eastern corridor of green belt with a distance coverage of 15.35m had a Nearest Neighbor Ratio of 0.41 with a critical Z-score value of -7.65 less than 1 (< 1); while in the western corridor *Oleandra distenta* with 21.73 distance coverage, recorded a Nearest Neighbor Ratio of 0.62 with a critical value (-4.75) less than 1. This implies the trend of clustering distribution between species of respective corridor and with the given critical values, there is a less than 1% likelihood that the clustered pattern could be the result of random chance. (Figs. 3.3 and 3.4)



Given the z-score of -7.645201, there is a less than 1% likelihood that this clustered pattern could be the result of random chance.

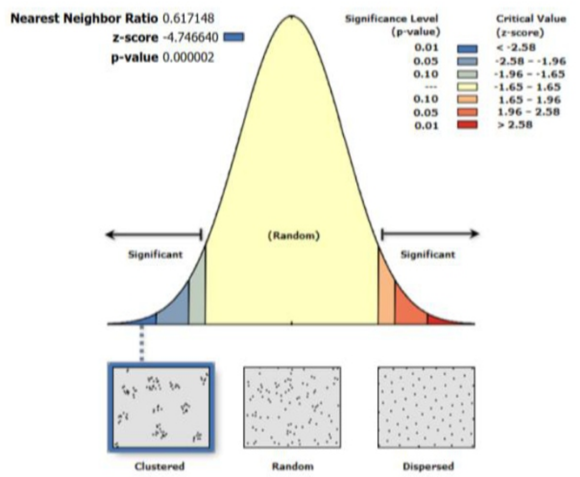
Average Nearest Neighbor Summary

Observed Mean Distance	15.3532 Meters
Expected Mean Distance	37.3760 Meters
Nearest Neighbor Ratio	0.410778
z-score	-7.645201
p-value	0.000000

Dataset Information

Input Feature Class:	Oleandra_Eastern_Belt
Distance Method:	EUCLIDEAN
Study Area:	257041.725350
Selection Set:	False

Fig 3.3. Nearest Neighborhood Analysis of eastern belt Oleandra distenta



Given the z-score of -4.74664, there is a less than 1% likelihood that this clustered pattern could be the result of random chance.

Average Nearest Neighbor Summary

Observed Mean Distance	21.7317 Meters
Expected Mean Distance	35.2131 Meters
Nearest Neighbor Ratio	0.617148
z-score	-4.746640
p-value	0.000002

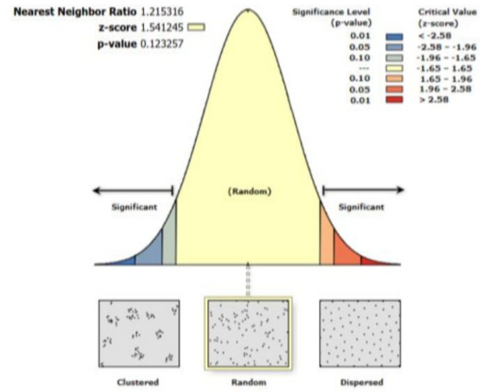
Dataset Information

Input Feature Class:	Oleandra_Western_Belt
Distance Method:	EUCLIDEAN
Study Area:	208313.834922
Selection Set:	False

Fig. 3.4. Nearest Neighborhood Analysis of western belt Oleandra distenta

Phymatode sclopendria

The pattern of distribution of *Phymatode sclopendria* at the eastern corridor of green belt as revealed by the Nearest Neighbor Ratio (1.22) with distance coverage (162.12m), exhibited random distribution pattern. Given a critical value of 1.54, the pattern does not appear to be significantly different than random distribution while the western corridor of green belt distribution with distance coverage of 19.27 meters, had a Nearest Neighbor Ratio of 0.48 and a Z-score with critical value (-5.90), This implies a clustered pattern of distribution, with a less than 1%; s likelihood that could be the result of random chance (Figs. 3.5 & 3.6)



Given the z-score of 1.541245, the pattern does not appear to be significantly different than random.

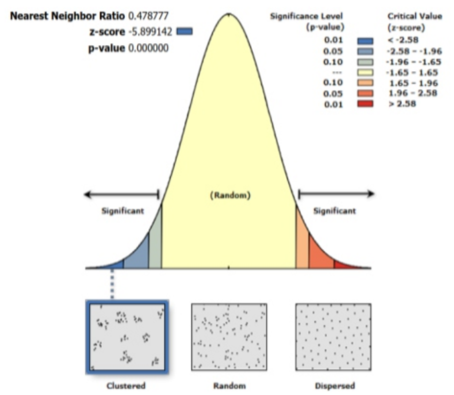
Average Nearest Neighbor Summary

Observed Mean Distance	62.1207 Meters
Expected Mean Distance	51.1148 Meters
Nearest Neighbor Ratio	1.215316
z-score	1.541245
p-value	0.123257

Dataset Information

Input Feature Class:	Phymatodes_Eastern_Belt
Distance Method:	EUCLIDEAN
Study Area:	146312.606039
Selection Set:	False

Fig. 3.5 Nearness Neighborhood Analysis of eastern belt Phymatodes sclopendria



Given the z-score of -5.899142, there is a less than 1% likelihood that this clustered pattern could be the result of random chance.

Average Nearest Neighbor Summary

Observed Mean Distance	19.2649 Meters
Expected Mean Distance	40.2379 Meters
Nearest Neighbor Ratio	0.478777
z-score	-5.899142
p-value	0.000000

Dataset Information

Input Feature Class:	Phymatodes_Western_Belt
Distance Method:	EUCLIDEAN
Study Area:	226671.896057
Selection Set:	False

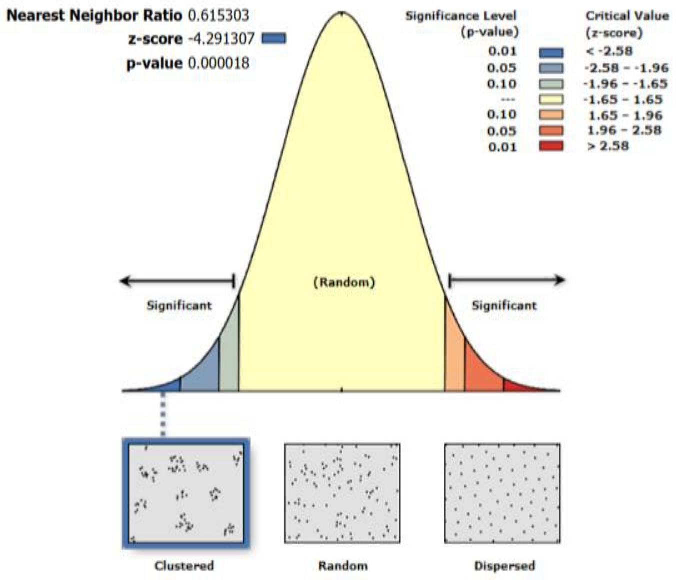
Fig. 3.6. Nearness Neighborhood Analysis of western belt Phymatodes sclopendria

Platycerium bifurcatum

The *Platycerium bifurcatum* on the eastern corridor of green belt with an average distance coverage of 29.50m had a Nearest Neighbor Ratio of 0.62 which is less than 1, signifying a clustered distribution pattern. Given a critical Z-score value (- 4.29), there is a less than 1% likelihood that the clustered pattern could be the result of random chance. The same species on the western corridor of green belt with a distance coverage of 4620.89 meters and a Nearest Neighbor Ratio of 0.62 greater than 1 recorded a dispersed distribution pattern (Figs 3.7 and 3.8).

Pyrossia mechowii

Pyrossia mechowii recorded a dispersed pattern at both the eastern and western corridors of green belt with a Nearest Neighbor Ratio of 2.87 and 2.00 respectively greater than 1, though at the distances of 552.51 and 139.29 meters. Given the critical Z-score values of 14.33 (eastern) and 4.66 (western), there is a less than 1% likelihood that the dispersed pattern could be the result of random choice (Figs 3.9 and 3.10).



Given the z-score of -4.291307, there is a less than 1% likelihood that this clustered pattern could be the result of random chance.

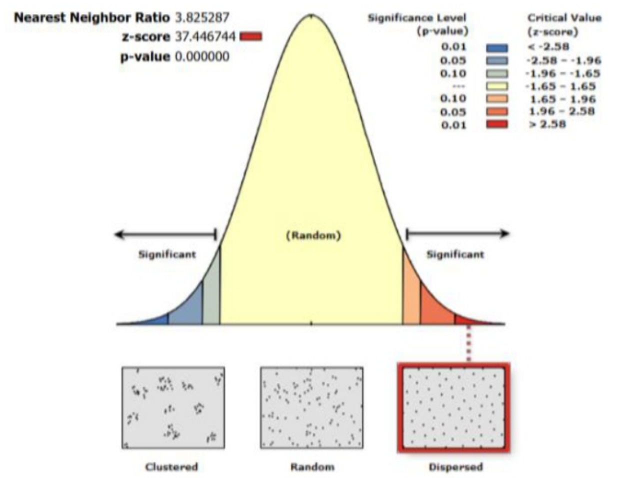
Average Nearest Neighbor Summary

Observed Mean Distance	29.4950 Meters
Expected Mean Distance	47.9358 Meters
Nearest Neighbor Ratio	0.615303
z-score	-4.291307
p-value	0.000018

Dataset Information

Input Feature Class:	Platycerium_Eastern_Belt
Distance Method:	EUCLIDEAN
Study Area:	312506.374727
Selection Set:	False

Fig 3.7 Nearest Neighborhood Analysis of eastern belt Platycerium bifurcatum



Given the z-score of 37.446744, there is a less than 1% likelihood that this dispersed pattern could be the result of random chance.

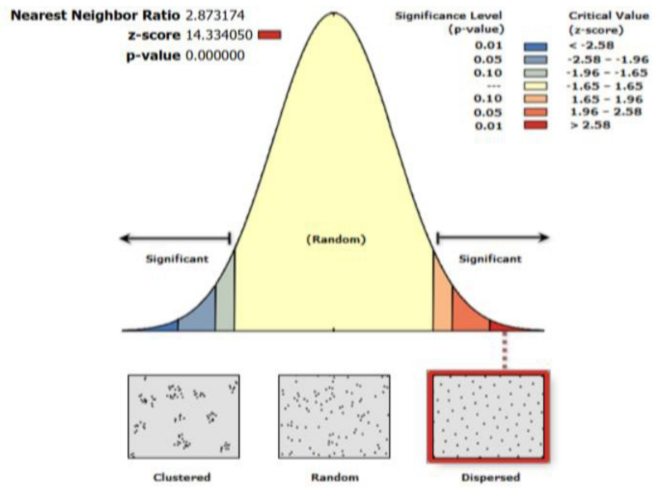
Average Nearest Neighbor Summary

Observed Mean Distance	4620.8868 Meters
Expected Mean Distance	1207.9844 Meters
Nearest Neighbor Ratio	3.825287
z-score	37.446744
p-value	0.000000

Dataset Information

Input Feature Class:	Platycerium_Western_Belt
Distance Method:	EUCLIDEAN
Study Area:	280171430.315838
Selection Set:	False

Fig 3.8 Nearest Neighborhood Analysis of western belt Platycerium bifurcatum



Given the z-score of 14.33405, there is a less than 1% likelihood that this dispersed pattern could be the result of random chance.

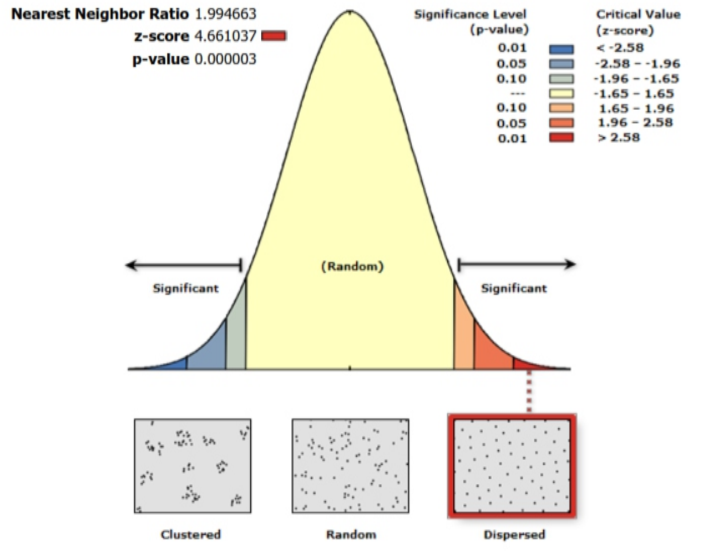
Average Nearest Neighbor Summary

Observed Mean Distance	552.5108 Meters
Expected Mean Distance	192.2998 Meters
Nearest Neighbor Ratio	2.873174
z-score	14.334050
p-value	0.000000

Dataset Information

Input Feature Class:	Pyrossia_Eastern_Belt
Distance Method:	EUCLIDEAN
Study Area:	2366670.687955
Selection Set:	False

Fig 3.9. Nearest Neighborhood Analysis of eastern belt Pyrossia mechowii



Given the z-score of 4.661037, there is a less than 1% likelihood that this dispersed pattern could be the result of random chance.

Average Nearest Neighbor Summary

Observed Mean Distance	139.2940 Meters
Expected Mean Distance	69.8333 Meters
Nearest Neighbor Ratio	1.994663
z-score	4.661037
p-value	0.000003

Dataset Information

Input Feature Class:	Pyrossia_Western_Belt
Distance Method:	EUCLIDEAN
Study Area:	117040.652994
Selection Set:	False

Fig 3.10. Nearest Neighborhood Analysis of western belt Pyrossia mechowii

4. DISCUSSION

The integrated use of conventional phytosociological tools, geospatial tools, and modern software technologies like the ArcGIS and the Average Nearest Neighborhood (ANN) Analysis to predict the phytosociology of species frequency and density, as well as the distribution pattern of epiphytic ferns in a green belt corridor in part of Rivers State, Nigeria, has revealed six different epiphytic ferns in the canopy formation.

The frequent occurrence and density of epiphytic ferns recorded on both greenbelt canopies (Tables 3.4a & b) have shown that *Oleandra distenta* (Eastern and western belt) has the highest frequency of occurrence (67.16%), followed by *Platycerium bifurcatum* (50.75%). On the western belt, *Platycerium bifurcatum* had the highest frequency of occurrence (70.59%), and then *Oleandra distenta* (61.67%). The species have exhibited variance in the transect subunit, revealing their dominance across horizontal gradients of individual phorophyte. This corroborates studies on the richness and abundance of epiphytic fern species on phorophytes along horizontal distribution [44, 45]. Similar reports have also revealed phorophytes with mid-level elevational gradients influencing the initiation, bearing, and colonization of more epiphytic fern species [46, 47, 48, 49].

Besides the elevational gradients of phorophytes, dominant species have been shown to have a sound resilience characteristic to adapt to the ever-changing climatic conditions of their environment [50]. This could be exemplified in this present study, where the level of humidity and rainfall experienced within the study area has greatly proven the influence of precipitation in the distribution pattern of these six epiphytic fern species along a horizontal gradient [51, 52, 53, 54].

By the phorophyte assessment of individual species on the western and eastern green belt, *Drynaria laurentii* remains the only epiphytic fern that appeared in one greenbelt location. This implies a very low level of adaptability compared to other epiphytic fern species recorded within the study site. This supports the assertion that the species requires very favorable abiotic and biotic conditions that will permit its growth and development because of their sensitive nature [20]. However, the influence of anthropogenic activity within the study site has revealed variation in the frequency of occurrence (presence and absence) of individual fern species across the green belt as represented in Table 3.3. It is shown that some epiphytic fern species, like *Phymatodes sclopendria,* have shown their absence in subunit 7 of the western belt and subunits 1, 6, and 10 of the eastern belt. *Nephrolepsis pumicicola* on the eastern belt was seen in all the subunits except in subunits 1,4,6,8 and 10, as well as in subunits 1, 6, and 11 of the western belt. *Pyrossia mechowii* was present in all subunits of the western belt except in 4, 5, 6, 7, and 11, and also of the eastern belt, present only in subunits 1,3,4,5,6,7,9 and 10.

The rate at which these epiphytic ferns are distributed along a horizontal gradient based on the nearest neighbour ratio has shown that a random and clustered pattern of distribution could possibly be as the result of litter accumulation and composition of the fronds at the greenbelt canopy and the activities of the micro and macro organisms of the individual phorophytes on which the fern species grow [55]. The clustered pattern of distribution by *Oleandra distenta* on both eastern and western wings has invariably indicated that the greenbelt canopy of the phorophytes did not affect the distribution. This reaffirms the assertion by Nervo *et al*. [19] that the distribution of arboreal epiphytic fern on a greenbelt canopy lies on the chance and limitations of their dispersal in different areas under different environmental gradients and canopy assemblages. This could also imply that the distribution of pteridophytes may be promoted by their higher dispersal abilities but restricted by habitat availability [56].

Though it has been reported that cryptogamic ferns are not randomly distributed but rather clustered or dispersed with their presence or absence relating to microhabitat characteristics and abiotic variables [57, 58]. In the present study *Platycerium bifurcatum* and *Phymatodes sclopendria* were found to be clustered on the eastern and western corridor green belt, respectively while attaining a dispersed and random pattern of distribution on the reverse side of the corridor belt, respectively. This has greatly shown that distribution pattern can be changed, altered or influenced by some abiotic and biotic determinants such as phorophyte bark texture and pH as well as anthropogenic activities like logging and canopy branching with attendant impact on individual distribution of the canopy belts [59]. With all the ferns having a common host*,* *Nephrolepis pumicicola* and *Pyrossia mechowii* with a dispersed distribution pattern on both green belt corridor indicates their weak ability to adapt to this kind of environment, unlike *Oleandra distenta*, *Platycerium bifurcatum* and *Phymatodes sclopendria,* this variation in distribution is likely to be caused by the phorophyte host bark structure and texture and pH [59].

However, the inability to have *Drynaria laurentii* on both sides of the study site might be a result of poor accumulation of litter based on the branching of the phorophytes which has limited its growth and distribution.

Anthropogenic activities such as clearing of story, logging, pruning of tree branches, or felling of whole trees often take place at the study site. All these activities as noted by Hietz *et al*. [60] and Kromer *et al*. [61] have an alteration impact on the natural environment and habitat and consequent changes in the diversity and distribution of ferns thus influencing their abundance as been revealed in the results. Such activities might also lead to species isolation, reduced cover, increased exposure to solar radiation and an increase in evapotranspiration rate, thereby modifying the microhabitat [62].

Conclusion

The use of geospatial technologies like the handheld GPS and ArcGIS has revealed the phytosociological attributes of six different arboreal epiphytic ferns. *Oleandra distenta*, *Platycerium bifurcatum* and *Phymatodes sclopendria* have shown have high adaptability ratios to withstand the climate of this region due to their high frequency of occurrence, which has invariably made them to have a clustered kind of distribution across the green belt canopies. Unlike *Pyrossia mechowii, Nephrolepis pumicicola* and *Drynaria laurentii* and coupled with their various adaptive features and shorter life span if compared to their hosts, this study has helped to understand their distribution as a window for conservation priority.

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Conflict of Interest

The authors declare no conflict of interest in any aspect of the study.

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