__Original Research Article__

Environmental Gradient: An ecological surrogate to phytosociological diversity of a tropical mangal-rainforest-ecotone in a hydromesic tripartite plant community.

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Aim: To assess influence of edaphic environmental gradients as surrogate to phytosociological diversity in a hyromesic habitat.

Study design: A systematic sampling approach of line-transect method was used.

Place and Duration of Study: Field sampling: tropical mangal-rainforest ecotone in parts of Asarama, Andoni, Niger-Delta, Labortory analysis: Jack Petroanalytical Laboratory, and University of Port Harcourt Ecology Laboratory, Port Harcourt, Nigeria, between September 2020 and August 2021.

Methodology: Soil sampling and analyses was based on ASTM, Stewarte and conventional methods and the data obtained was subjected to statistical analysis.

Result: recorded 90 plant species across the sampled sites with a prevalence of 6 (65.9%) species in mangrove, 64 (70.33%) in ecotone and 55(60.44%) in rainforest sites respectively. Floristic density and life form in mangrove had 121ha^{-1}, 3 megaphanerophytes and mesophanerophytes respectively, in ecotone 1660ha^{-1}, 9 megaphanerophytes, 24 mesophanerophytes and 39 microphanerophytes and in rainforest 574ha^{-1}, 13 megaphanerophytes, 18 mesophanerophytes and 24 microphanerophytes. Highest frequency of occurrence: 1 species (80%), 4 species (100%) and 1 species (80%) in mangrove, ecotone and rainforest sites respectively. Highest abundance: mangrove (1 species), ecotone (9 species) and rainforest (3 species). Highest density: mangrove (1 species), ecotone (8 species) and rainforest (3 species). Distribution: greater in ecotone with contiguous pattern in the order: *ecotone>rainforest>mangrove*, among which had dissimilarity in response to significant species diversity difference in relation to significant difference in edaphic physico-chemical factors of the study sites. The mangrove site had the most acidic pH, highest salinity, moisture and electrical conductivity while rainforest and ecotone had highest organic carbon and matter. A significant negative correlation between EC & pH, and salinity & pH and positive correlation between salinity & EC as well as positive correlation between pH & OC, pH & OM, OC & OM and negative correlation between EC & OC, EC & OM were recorded.

Conclusion: This variation determined the presence, growth and abundance of the species reported in the respective study sites especially in the ecotone.

Key Words: *Species diversity, similarity index, frequency, density, abundance*

1. INTRODUCTION

The Niger Delta rainforest has been described as lowland moist tropical rainforest and a complex zone with unique evergreen species diversity [1]. It is the richest, and most luxuriant of all plant communities occurring in areas of wet tropical climate and less dry seasons [2]. This unique vegetation type is represented in only wet and / or moist forests based on the amount of rainfall it receives, elevation and varying soil types. The vegetation forest includes the mangrove forest, fresh water swamp forest, montane forest and the tropical rainforest, which consists of trees, mosses, small stemmed shrubs, lichens, herbs and ferns in at least four different strata [3]. Tropical rainforest soils are characterized by heavy leaching and poor nutrients as a result of the amount of annual rainfall. However, topsoil is nutrient-rich due to rapid decomposition of organic matter (leaf litters) as a result of temperature and rainfall [1].

A mangal – tropical rainforest ecotone as its name implies is a transition zone sandwiched between and consist of a mangrove and tropical rainforest vegetation with varying structural diversity of flora composition. In other words they are heterogeneous vegetation zones situated between two homogeneous plant communities [4]. To further expatiate, ecotones can represent a broad transition between different biomes, such as a slow but steady conversion between forest and grassland or a very narrow and well -defined terrestrial-aquatic boundary [5]. It is worthy to note that the phytosociological attributes on both sides of any ecotone will be dissimilar to one another. This is due to variability in vegetation cover based on gradient abiotic factors that may characterize ecotones [5].

Mangal vegetation is a general name for several species of plant which can survive in saline environments [6]. Such vegetation is mostly represented by the mangroves consisting of five species found within three endemic families (Combretaceae, Rhizophoraceae and Avicenniaceae), and the introduced family (Arecaceae) of exotic species (*Nypa fruticans*) [7,8] and other associated halophyte including *Paspalum vaginatum, Dalbergia ecastaphyllum, Conocarpus erectus, Machaerum lunatum* ans *Acrostichum aureum* in the Niger Delta [9]. This is as a result of its peculiar edapho-environmental gradients characterised by poorly aerated and water logged mud flat soil types, chikoko soil, six-hourly tidal inundations, acidity, high salinity and high moisture contents [9,10,11].

Phytosociology, a branch of science deals with plant communities, their composition and development, and the relationships between the species within them [12]. Phytosociological variation of forest vegetation types could be as a result of gradation in the continuous interaction of climatic conditions such as temperature, humidity, rainfall patterns (moisture) [13] and soil types [14]. In essence, the phytosociology of any geographical area are responses to their abiotic factors which encompasses climatic, edaphic and topographic factors [15, 16, 17] present in their environment.

Environmental gradient refers to the variation or gradual change among abiotic factors through space (or time) [18]. Such gradients are responsible for the difference in vegetal phytosociology and variations as they visibly express their ecological impact or influence [19]. Thus, the absence, presence, distribution and abundance of plant species in any environment are dependent on their ability to respond and adapt to variation or changes in abiotic factors. Physiological characteristics of a species can be said to determine its occurrence in an environment with certain gradient levels because some characteristics favour fast growth in ideal conditions or levels while others in demanding or stressful conditions. Consequently, not all species are present in all parts of the world because of these multiple factors affecting them.

The rationale for this study is on the basis that every vegetation type in the world has its uniqueness and peculiarities revealed by the effect of the environmental gradients or factor. These are the primary determinants of the presence, absence, composition, abundance or distribution and diversity of species around the world [19]. However, there is paucity of information explaining the ecological influences of environmental gradients in the phytosociology of varying vegetation types in the Niger Delta. This study is aimed at analysing the impact of environmental gradients on the phytosociology of mangal-tropical rainforest ecotone with the objectives of analysing the phytosociology within and among the mangal-tropical rainforest ecotone and secondly evaluating the correlative relationship of some physicochemical parameters of the soil ecosystem to the variance of the vegetation types in the study sites at Asarama, Andoni

2. MATERIALS AND METHODS

2.1. Study area, location and site.

Rivers State is one of the thirty-six States, located between longitudes $6^{o}23^{'}$ E and $7^{o}6^{'}$E and latitudes $4^{o}18^{'}$N and $5^{o}45^{'}$N of the equator (Fig. 1) in parts of the Niger Delta, Nigeria. The State is geographically bounded to the east by Imo River and Akwa-Ibom; the West by Bayelsa State; the North by Imo State and Abia State and the South by the Atlantic Ocean [20]. The vegetation zones of Rivers State comprises of the mangrove forest, coastal barrier islands, fresh water swamp and the tropical rainforest [1]. The area is characterized by tropical hot monsoon climate due to its latitudinal position associated with heavy rainfall (2000mm to 2500mm); average temperature (23.00 to 42.60°C) all year round and a relative humidity between 65% to 96.80% [21, 22]. Its relief is generally lowland with an average elevation of 20m to 30m above sea level [21, 22, 23, 24,]. The edaphic condition is characterized by sandy silt, sandy loam or clayey underlain by a section of impervious pan often leached and alkaline or salty and sometimes acidic in nature as a result of heavy rainfall [25]. Rivers state consist of twenty-three (23) local government council including the study location- Andoni (Fig.1) [26].

Andoni study location with its geographical situate at Latitude $4^{o}32^{'}57^{o}$N and Longitude $7^{o}26^{'}47^{o}$E is bordered to the North by Khana; to the West by Bonny; to the East by Opobo / Nkoro local government council and to the south by the Atlantic Ocean. It has 11 towns / communities including Asarama study site (Fig 1.).

2.2. Land Use Ecology/Human Resource Interaction:

The degree of land use ecology and human resource interaction of the sample plots of the study sites was assessed through actual observation of natural and human disturbances and intrusions using the Focused Group Discussion (FGD) and Key Informant Interview (KII) [26].

2.3. Flora Assessment and Identification

The Braun-Blanquet relieve approach [27] (a systematic randomly stratified line-transect method) was adopted. Each study site with sampled plot (100m x 35m) taken 10m away from the unity road was measured. Each sampling plot had five (5) sub-sampling units (20m × 35m) (Fig.2). Thus, giving a total of 15 sub-sampling units in the three sampled plots of the study site. The sub-units were based on the vegetation structure of the location due to the observable environmental gradient of altitude. All the important representative plant species were identified in the field as much as possible and properly authenticated using reference books such as Burkill [28,29,30,31, 32] and Floras such as Hutchinson and Dalziel [33, 34, 35, 36, 37] and Keay [38].

Fig. 1: Rivers State showing Andoni study location

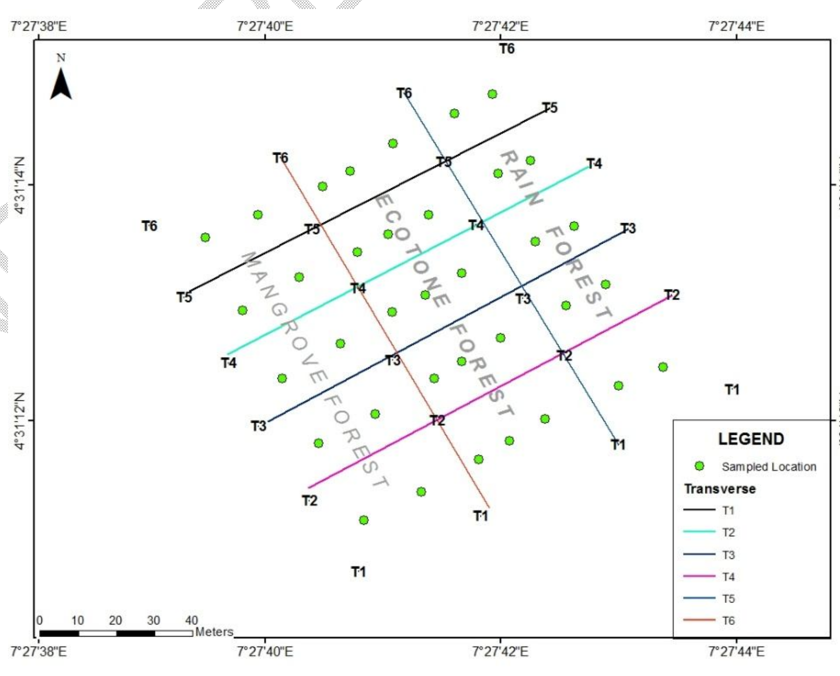

Fig. 2: Transect Direction of Sampled Plots of the study site.

2.4. Phytosociological Analysis

The species quantitative analysis was based on the standard phytosociological indices of abundance, frequency of distribution and density of the species [39, 40, 41]; relative frequency, relative abundance and relative density [42]; Important Value Index (IV1) [43], species diversity in terms of richness [44] index and Margalef [45] respectively and evenness or equitability [46] methods, and similarity and dissimilarity of the sampled plots using Jaccard similarity Index (C_J) [47]. Species distribution pattern (abundance-frequency ratio) [48]; in accordance with the 'Rule of Thumb' exemplified as Regular (< 0.03), Random (0.03- 0.05) and contiguous (> 0.05) were adopted. The Life Form description based on habit and environmental adaptation [49, 50] were explored.

2.5. Soil Sample Collection and Analysis

Soil samples were taken at surface or topsoil (0-15cm) and sub-surface levels (15-30cm) at the 15 sub-sampled plots in each sampled site. The samples were put in zipper polybags and labelled according to their respective sampled plots [51]. The coordinates of the sampled points were recorded using Garmin etrex GPS 20 model (Table 1). Samples were air dried, ground and sieved using a 0.5cm mesh or sieve to get fine particles and then transferred to the laboratory for physico-chemical analyses. Soil pH determination was by using pH meter (model-H198107) [52]. Soil Conductivity (µS/cm) was determined using conductivity meter (DDS-307) [53]. Soil Salinity was extrapolated by multiplying conductivity value by 1.0878 and 0.4665 after dividing such conductivity value by 1000. It can be deduced mathematically as expressed in the formula: $R = F \times 1.0878 \times 0.4665$; Where R = Soil salinity value; F= soil conductivity value [54]. Moisture content (%Wt) determination was based on Australian Standard (AS 1289 B1.1) [55]. Organic carbon analysis was based on Walkley and Black [56] while Organic Matter (OM) was extrapolated by multiplying carbon value with a constant 1.724. Data analysis was by SAS software [57] used to test the variance on the soil physico-chemical parameter of all sampled plots of the study site at 0.05% level of significance. PAST software was used to carry out some species indices among sampled plots of the study site at 0.05% level of significance.

Table 1: GPS Coordinates of sampled point of the sampled sites

Sampled Plots	Mangrove Coordinates		Ecotone Coordinates		Rainforest Coordinates	
	Long (E)	Lat (N)	Long (E)	Lat (N)	Long (E)	Lat (N)
Transect 1	7.46151°	4.52056°	7.46144°	4.52083°	7.46164°	4.52057°
	7.46158°	4.52050°	7.46160°	4.52073°	7.46142°	4.52096°
	7.46144°	4.52083°	7.46164°	4.52057°	7.46144°	4.52091°
Transect 2	7.46160°	4.52058°	7.46152°	4.52068°	7.46153°	4.52041°
	7.46169°	4.52052°	7.46144°	4.52054°	7.46131°	4.52079°
	7.46152°	4.52068°	7.46153°	4.52041°	7.46133°	4.52079°
Transect 3	7.46132°	4.52064°	7.46121°	4.52054°	7.46140°	4.52030°
	7.46140°	4.52069°	7.46131°	4.52038°	7.46114°	4.52066°
	7.46121°	4.52054°	7.46140°	4.52030°	7.46121°	4.52063°
Transect 4	7.46124°	4.52065°	7.46115°	4.52038°	7.46127°	4.52019°
	7.46131°	4.52060°	7.46121°	4.52025°	7.46101°	4.52058°
	7.46115°	4.52038°	7.46127°	4.52019°	7.46104°	4.52053°
Transect 5	7.46110°	4.52040°	7.46101°	4.52024°	7.46119°	4.52004°
	7.46115°	4.52035°	7.46110°	4.52021°	7.46087°	4.52045°
	7.46101°	4.52024°	7.46119°	4.52004°	7.46098°	4.52040°

3. RESULTS

3.1. Phytosociological frequency of individual species prevalence

The study has recorded a total representative of 90 plant species (Table 2) though with variation among sampled sites in which mangrove recorded 6 species (6.59%), ecotone 64 species (70.33%) and rainforest 55 species (60.44%) distributed under 38 families. The three study sites had just one (1) species (*Nypa fruticans*) of the Arecaceae family in common.

3.2. Floristic composition of species density (ha^{-1}) and life form

The mangal study site recorded a total representative of 121 ha^{-1} of individual species distributed under four (4) families (Arecaceae, Rhizophoraceae, Combretaceae, Avicenniaceae) in both discrete and continuum heterogeneity (Table 3). The most dominant species was *Nypa fruticans* (Arecaceae) while the least dominant was *Rhizophora mangle* (Rhizophoraceae). The life form structural classification of the study site recorded three species in three families as mesophanerophytes and three species in two families as megaphanerophytes and devoid of herbaceous microphanerophytes.

The ecotonal study site had a total representative of 1660 ha^{-1} of individual species under 30 families (Table 3) distributed in continuum heterogeneity. The most dominant species were *Paspalum vaginatum*, and *Fimbristylis littoralis* while *Ficus sagittifolia*, *Alchornea laxiflora* and *Maesobotrya barteri* were the least dominant in species prevalence. The life form structural classification of this site recorded nine species as megaphanerophytes distributed in five families dominated by Loganiaceae; 24 species as mesophanerophytes distributed in 15 families dominated by Euphorbiaceae and Apocynaceae and 39 herbaceous species as microphanerophytes distributed in 18 families dominated by Cyperaceae family.

The rainforest study site recorded a total representative of 574 ha^{-1} of individual species under 27 families distributed in continuum heterogeneity (Table 3). The most dominant species in this study site are *Lygodium smithuanum*, *Anthocliesta nobilis* and *Tetracera alnifolia* while *Nypa fruticans*, *Lannea acida, Acrosticum aureum* and *Ficus polita* were among the least dominant species in terms of individual number of species. The life form structural classification of the study site recorded 13 megaphanerophytes distributed in nine families dominated by Loganiaceae; 18 mesophanerophytes under 11 families dominated by Apocynaceae and 24 herbaceous microphanerophytes under 17 families dominated by Cyperaceae and Arecaceae.

3.3. Phytosociological Composition

i. *Frequency of occurrence*

The result indicates that in the mangrove study site one species (*Rhizophora harizonii)* recorded the highest percentage 80 (23.53%) frequency of occurrence (Table 4). The ecotone study site recorded four species (*Nypa fruticans, Anthocleista liebrechtsiana, Acrostuicum aureum* and *Lygodium microphyllum*) with the highest percentage 100(3.88%) frequency of occurrence (Table 5), while the rainforest had one species (*Anthocleista liebrechtsiana*) with the highest frequency of 80 (4.30%) occurrence, (Table 6).

ii. *Abundance*

Nypa fruticans had the highest abundance of 29 (58%) in mangrove site (Table 4), while the ecotone recorded nine (9) species (*Fimbristylis littoralis, Fuirena ciliaris, Cyperus sp., Delbergia ecastaphyllum, Melastomastrum capitatum, Paspalum vaginatum, Pycreus lanceolata, Sabicea geophiloides,* and *Selaginella myosurus)* with maximum abundance range values (25 – 75.00) (3.15% - 9.46%) amongst which *Selaginella myosurus* and *Paspalum vaginatum* had the highest abundance of 75(9.46%) and 58.33(7.36%) respectively (Table 5). The rainforest study site recorded three species (*Heterotis rotundifolia, Oplismenus burmanii,* and *Lygodium smithianium)* of maximum abundance range of 25.00-30.00 (4.4% - 8.87%) with *Heterotis rotundifolia* having the highest abundance of 30 (8.87%) (Table 6).

iii. *Density (ha^{-1})*

The mangrove study site, recorded one species (*Nypa fruticans*) with the highest density of 11.6 (47.93%) ha^{-1} (Table 4). The ecotone recorded eight (8) species (*Crinum jagus*, *Fimbristylis littoralis*, *Delbergia ecastaphyllum, Maesobotrya barteri, Paspalum vaginatum*, *Sabicea geophiloides, Lygodium microphyllum,* and *Selaginella myosurus*) with a maximum density range of 15-36 ha^{-1} (4.42% - 9.90%). However, *Crinum jagus* and *Fimbristylis littolaris* recorded the highest density values of 36 ha^{-1} (9.90%) respectively which were closely followed by *Paspalum vaginatum* with density values of 35 ha^{-1} (9.62%) (Table 5). The rainforest recorded only three (3) species with maximum density range of 7-10 ha^{-1} (6.18% - 8.83%) with *Lygodium smithanium* recording the highest density of 10 ha^{-1} (8.83%) (Table 6).

iv. *Importance Value Index (IVI)*

The *Nypa fruticans* had the highest Importance Value Index of 117.69 (9.88%) recorded in mangrove site (Table 4). The ecotone recorded six species (*Fimbristylis littoralis, Paspalum vaginatum, Pycreus lanceolata, Sabicea geophiloides, Lygodium microphyllum,* and *Selaginella myosurus)* with maximum Importance Value Index of 10.00 – 19.31(3.79% - 6.66%) with *Paspalum vaginatum* having the highest IVI of 19.31 (6.66%) (Table 5). The rainforest had eight species (*Cynotis lanata*, *Tetracera alnifolia, Anthocliesta nobilis, Heterotis rotundifolia, Oplismenus burmanii, Sabicea geophiliodes, Lygodium smithianium, and Selaginella myosurus)* with maximum IVI ranging from 11.00 – 18.53 (3.94% - 6.07%) and *Lygodium smithianium* recording the highest IVI of 18.53 (6.07%) (Table 6).

v. *Species diversity*

The margalef index of richness has recorded the least value (3.79) for the mangrove study site, the ecotone study site with 25.81 and the rainforest study site (24.99).

The highest Shannon Weiner Index of species diversity richness (62.66) and evenness (80.52) in mangrove habitat was recorded with *Nypa fruticans* while in ecotone was *Paspalum vaginatum* with diversity richness (5.48) and evenness (3.02); and *Lygodium smithianium* richness (4.75) and evenness (2.14) in the rainforest study site.

vi. *Distribution pattern*

The species distribution pattern in mangrove site recorded 33.33% randomness in two species (*A. germinans* and *R. harizonii*) with greater distribution of contiguous pattern (66.67%) among four species in which *Nypa fruticans* had the highest (0.73) (Table 4). The ecotone had one species with 1.56% regular distribution pattern while 9.38% randomness was recorded among six species and 89.06% of contiguous pattern was recorded among 57 species with *Selaginella myosurus* having the highest (3.75) in distribution (Table 5). The rainforest site (Table 6) had 1.82% regular distribution pattern with one species, 25.46% random pattern with 14 species and 40 species recording 72.73% contiguous pattern with *Heterotis rotundifolia* having the highest (1.50) contiguous pattern of distribution.

vii. *Similarity and dissimilarity index*

Using the Bray-Curtis similarity and dissimilarity index, there existed dissimilarity between the mangrove and ecotone study site with its value (0.02) less than 0.5; dissimilarity between mangrove and rainforest study sites with value (0.02) less than 0.5 and also dissimilarity between the ecotone and rainforest study sites with value (0.4) less than 0.5 (Fig.3). Based on the Jaccard Index the various plant community recorded greater dissimilarity than similarity among each other. Between the mangrove and ecotone was a higher dissimilarity value of 98.57% than similarity (1.48%) and similarly was the mangrove and rainforest with 98.38% dissimilarity than 1.61% similarity index, while the ecotone and rainforest plant community was 77.27% dissimilarity than 22.73% similarity.

3.4. Soil Physico-Chemical Analysis

Soil pH

Soil pH across study sites had no significant (*P=.05*) difference at surface level but the rainforest soil (4.72) was significantly (*P=.05*) higher than the ecotone soil (4.64) which was slightly higher than the mangrove soil (4.24) in pH value. At the sub-surface levels, the pH value in the mangrove soil (3.40) also recorded variation (*P=.05*) from the respective study sites at this level. The rainforest soil (5.24) recorded the highest pH value at this level though non-significantly higher (*P=.05*) than ecotone soil (4.82) but significantly (*P=.05*) higher than the mangrove soil (3.40). Generally, the soil pH revealed no significant difference across the study sites at surface and sub-surface soil except at the Mangrove sub-surface soil (MSS) which was significantly(*P=.05*) different from others with the lowest pH values while the rainforest sub-surface soil (RSS) recorded the highest pH value (Table 7).

Within the study sites, the mangrove soils had its pH value significantly different (*P=.05*) between the surface and sub-surface soils; with the surface soil pH higher than the sub-surface soil pH while the sub-surface soil recorded a higher pH than the surface soil with non-significant variation (*P=.05*) in the ecotone habitat. Also, the surface soil pH value significantly lower (*P=.05*) than the sub-surface soil pH was noted in the rainforest study site.

Soil Moisture Content (wt %)

Generally, the moisture content recorded a non-significant difference (*P=.05*) at the surface and sub-surface levels across the three study sites. However, the mangrove subsurface and rainforest surface soils recorded the highest and lowest moisture content value respectively (Table 7). At surface levels, the mangrove soil (47.31wt %) had the highest moisture content value amongst the soils from the other sites at this level while at Sub-surface levels; the mangrove soil (47.33wt %) recorded the highest moisture content value amongst the soils from the other sites at this level. At the mangrove study site, its sub-surface soil recorded a greater moisture content value compared to its surface soil. The ecotone study site sub-surface soil (47.12wt %) recorded same moisture content value with its surface soil (47.12wt %). Similarly, at the rainforest study site (41.30wt %) the sub-surface soil recorded a greater moisture content value than its surface soil (41.29wt %).

Soil Electrical Conductivity (μS/cm)

The EC value across the study habitats showed a significant difference (*P=.05*) at the mangrove soil surface level (3753μS/cm) with higher EC than other sites. Ecotone soil (1165μS/cm) was non-significantly higher than the rainforest soil (331μS/cm) at the surface level. Furthermore, the mangrove soil (3085μS/cm) recorded the highest EC value at sub-surface; non-significantly higher than the ecotone soil (953μS/cm) but significantly different (*P=.05*) from the rainforest soil (312μS/cm). Generally, mangrove surface soil recorded the highest electrical conductivity value with its value significantly different (*P=.05*) from all other soils of the surface and subsurface levels except the mangrove subsurface soil whose value was non-significantly lower (*P=.05*) to it (Table 7).

Within study site, the surface E.C value was non-significantly higher (*P=.05*) than that sub-surface at the mangrove habitat while the ecotone surface recorded a higher E.C than its sub-surface soil with no significant difference (*P=.05*). The rainforest study site recorded the lowest EC values at both levels despite a non-significant difference (*P=.05*) of higher surface EC to its subsurface.

Soil Salinity (ppt)

The mangrove subsurface soil (1.57ppt) recorded the highest salinity level and was significantly different (*P=.05*) from all others at both surface and subsurface levels across the study sites (Table 7). The salinity level across the study site was non-significantly higher (*P=.05*) in the surface mangrove soil (0.91ppt) than the ecotone soil (0.59ppt); which was non-significantly higher than the rainforest soil (0.17ppt); which was significantly different (*P=.05*) from the mangrove soil. The mangrove soil (1.57ppt) recorded the highest salinity level at the subsurface; significantly different (*P=.05*) from ecotone (0.48ppt) and rainforest soils (0.16ppt). Ecotone soil revealed a salinity level that was significantly (*P=.05*) higher than the rainforest soil at the subsurface.

Within study site, the subsurface soil has revealed a higher salinity; significantly different (*P=.05*) from its surface soil at the mangrove study site. The ecotone and rainforest study sites recorded a higher surface soil salinity level non-significantly different (*P=.05*) from their sub-surface soil.

Soil Organic Carbon (wt %)

Generally, the soil organic carbon content was highest in the rainforest surface soil (2.38wt %); significantly different (*P=.05*) from the mangrove subsurface soil (1.51wt %) which recorded the lowest organic carbon content (Table 7). The rainforest soil recorded the highest organic carbon content at soil surface (2.38wt %) and sub-surface (2.17wt %); non-significantly higher (*P=.05*) than those of the ecotone and mangrove soils.

Within the Study Site; the organic carbon content at the mangrove surface soil (2.05wt %) was non - significantly higher than the sub-surface soil (1.51wt %). The ecotone soil organic carbon content at the surface soil (2.07wt %) was slightly lower than that in the subsurface soil (2.08wt %) while the rainforest surface soil organic carbon content was non-significantly higher than its subsurface soil.

Soil Organic Matter (wt %)

Among the studied sites, the rainforest soil recorded the highest organic matter content at soil surface; non - significantly higher (*P=.05*) than the ecotone and mangrove soils while at Sub-surface Levels; the rainforest soil was significantly different (*P=.05*) and recorded the highest organic matter content amongst others. Generally, the soil organic matter content was highest in the rainforest subsurface soil (4.94wt %); significantly different (*P=.05*) from the mangrove subsurface soil (2.61wt %) which recorded the lowest organic matter content (Table 7).

At the mangrove study site; the organic matter content of the mangrove sub-surface soil (2.61wt %) was non - significantly lower than the surface soil (3.56wt %) while the ecotone (3.60wt %) and rainforest sub-surface (4.94wt %) soils had their organic matter contents slightly higher than their surface soils (ecotone (3.58wt %) and rainforest (4.12wt %) content with non-significant difference (*P=.05*).

4. DISCUSSION

Plant ecologists are concerned with patterns of species response to environmental gradients [58; 59] and to adapt a continuum approach to vegetation with its position in the multi-dimensional environmental space [60]. The three study sites within the study location have recorded variation in their floristic and species composition. This can be as a result of the ecological influence of the environmental gradients prevalent in the various habitats. The three study sites at surface and subsurface soil levels showed some significant differences in some of their physiochemical properties involving: pH, moisture content, electrical conductivity, salinity, organic carbon and organic matter. This corroborates several studies on the differences between surface and sub-surface soils physicochemical properties [5; 26; 61; 62; 63]. Frequency expresses biological abundance and dominance of vegetation reflecting its species composition and spatial pattern of vegetation in communities; measuring the uniformity of species distribution [26; 64]. The ecotone study site which is the transition zone/ site in contrast to the adjoining studied sites recorded the highest number of species and total individual number amounting 64 and 1660 (Tables 2 & 3).

The ecotone study site displayed the highest abundance of *Selaginella myosurus* and *Paspalum vaginatum* followed by *Heterotis rotundifolia* of the rainforest study site and *Nypa fruticans* of the mangrove study site. The abundance of *Nypa fruticans* in the mangrove study site revealed the effect of human activities by the over exploitation of the mangrove species creating an edge effect by the invasion of this palm. Due to the undiscovered usefulness of this palm by local inhabitants, it is not harvested for anything thus leading to an increase in its abundance and with its seeds moving under a high tidal influence anchoring any substrate. *Nypa* palm's presence in the rainforest and ecotone study sites can probably be attributed to its movement, transfer, deposition and anchorage of the seed at an ebbing tide and high tidal overflow of shoreline in land ward direction especially in rainy season as reported by the Key Informant.

In the rainforest site, the five families recorded were abundantly rich in species diversity among the fifty-five species; while the ecotone site had six of the 30 families abundantly rich in species among the 64 species and the mangrove study site had one family (Rhizophoraceae) rich among the four families in species diversity of the six species present (Table 2). This corroborates several studies on the high heterogeneity and high species diversity of ecotones [4; 5; 65; 66]. The family Rhizophoraceae was richest in species diversity accounting for three (3) *Rhizophora* species at the mangrove study site; thus corroborating the reports of James *et al.* [7] who reported the Rhizophoraceae family as having the highest species diversity in the Nigerian mangrove forest. In the ecotone study site, Cyperaceae the sedge family recorded the highest species diversity richness. This reveals that the site is under the influence of human disturbance as well as an indicator that the ecotone is a wetland or moist environment as earlier reported by Kantrud and Newton [67] and Edwin-Wosu and Anaele [26] on cyperaceae species indicating human interference in primary vegetation. The family Arecaceae recorded the highest species diversity richness in the rainforest site (Table 2). Species richness has been extensively reviewed and with its patterns of richness being determined by the interaction of disturbance with environmental gradients [68].

In life form classification based on habitat adaptation of species, (as exemplified in Table 3) the mangrove study site revealed an equal distribution of megaphanerophyte and mesophanerophyte. This can be attributed to the anatomical and physiological complexities, structures and adaptations acquired by mangal species due to the nature of their narrow niche adaptation in the environment devoid of microphanerophytes. The rainforest site disclosed a moderate distribution of its species adaptation within the 'mega-', 'meso-'and microphanerophyte life forms. Based on recorded field observation, this rainforest site revealed very thick and dense vegetation with different canopy layers of trees, shrubs, herbs and epiphytes corroborating Ayanlade [3] who had reported on different canopy stratum in rainforest vegetation. However, the minimal presence of microphanerophytes indicates the site was faced with human interference as a result of its land use ecology [26]. The ecotone study site revealed the maximum presence and distribution of the microphanerophytes (as exemplified in Table 3) amongst the other life forms. This site received maximum human disturbance which corroborates Edwin-Wosu and Anaele [26] on the presence of microphanerophytes as an indicator of human interference. Individual species diversity and evenness was observed to be highest in *Nypa fruticans* in the mangrove study site (Table 4) followed by *Paspalum vaginatum* and *Lygodium smithianium* in the ecotone (Table 5) and rainforest sites (Table 6) respectively. The mangrove study site had the least species composition in density and IVI which is as a result of its limited number of species due to its narrow niche adaptation of extreme environmental and soil conditions [69]. Based on field observation and key informant interview, the nature of the ecotone vegetation, soil condition and type as well as its position between the mangrove and rainforest rendered it a key hot spot of incursion by the local inhabitants as they create pathways to easily assess the adjacent sites. This is to enable them engage in their activities involving perinwinkle harvesting, fishing and fuel wood harvesting from the mangrove site and gather fuel wood, food, hunt for bush meat and gather parts of plants for ethno-medicinal purposes and other value chain resources from the rainforest site and the ecotone.

The usefulness of any similarity index lies in its ability to yield a true ecological picture of the species diversity richness of a given community. Any index which effects the realization of such a result is acceptable for the study of ecological diversity of a community. The Bray-Curtis and Jaccard similarity and dissimilarity index revealed great dissimilarity and significant difference in the species composition among the three study sites. The Bray-Curtis dendogram and Jaccard index revealed a close relationship between the rainforest and the ecotone study sites. This revealed that the ecotone study site recorded more species in the order: *ecotone* > *rainforest* > *mangrove* site. However, it is known that the African mangrove vegetation has a limited number of species because they are associated with a narrow niche adaptation of their environment as habitat specialist and cannot exist outside of such environment [69; 70]. A positive relationship between plant-species richness and rainfall (a surrogate for water availability) an environmental variable that accounted for greatest variance in species richness has been reported [71]. This also corroborates a positive correlation between mean annual rainfall and woody species [72; 73]. The rainforest is one of the richest vegetation types around the world [74; 75] and the species found in the ecotone study site co-existed with a number of mangal associated species that can exist in wetlands (e.g. *Paspalum vaginatum* and *Acrosticum aureum*). It can be deduced that two plant community of the same sampling location and with the same season of sampling are dissimilar than similar, hence there was significant species diversity difference in terms of richness due to disparity in sampled site, possibly in relation to significant difference in edaphic physico-chemical factors of the areas under study. Furthermore, the distribution and abundance of species across the three vegetation types as largely influenced by these environmental gradients (edaphic abiotic factors and biotic (anthropogenic factors) has been revealed.

Mangrove soils are known to be acidic under ebbing tidal condition as well as highly saline and water-logged under high level tidal inundation which is the reason for the limited species diversity in this ecosystem. The least and most acidic pH, highest salinity, moisture content and electrical conductivity were recorded in the mangrove at sub-surface and surface soils. This corroborate the reports of Dublin-Green and Ojanuga [76], Alongi *et al*. [77], Reef [78] and Oyebanji *et al.* [11] on mangrove soil physicochemical properties. This was followed by the ecotone and rainforest respectively at surface and subsurface soils. The variations encountered in the soil salinity levels of the different vegetation sites are as a result of the distance from the coast and tidal inundations [70]. These increase or decrease in the pH, EC, salinity of the study sites are supported by the significant negative correlation (r = -0.49; *P=.05*) between EC and pH; and (r = -0.55; *P=.05*) between salinity and pH and strong positive correlation (r = 0.54; *P=.05*) of salinity and EC. As EC and salinity increases the pH decreases while as EC increases the salinity also increases within all the study sites.

The organic carbon and organic matter were highest in the rainforest study sites at surface and subsurface levels followed by the ecotone and lastly by the mangrove site. This is supported by the strong positive correlation (r = 0.59; *P=.05*) between OC and OM. In an increasing order, the OC and OM content respectively in the soils are; *MSS<MS<ES<ESS< RS<RSS.* This is a result of the large amount of leaf litters that fall and decompose daily in the rainforest, and ecotone (due to its species composition) and the decaying prop roots and

leaf litters in the mangrove study site. In addition, study sites (rainforest) with higher pH had greater organic matter and organic carbon compared to sites with lower or more acidic pH. This is supported by the positive correlation (r = 0.08; *P=.05*) between pH and OC and (r = 0.27; *P=.05*) between pH and OM and negative correlation (r = -0.41; *P=.05*) between EC and OC and (r = -0.43; *P=.05*) between EC and OM and due to the positive correlation (r = 0.54; *P=.05*) of Salinity and EC.

However, the following edaphic environmental gradients including salinity, pH, electrical conductivity, moisture content, organic matter and organic carbon have played major roles in the presence or absence as well as the abundance of species in the three studied sites. Furthermore, the distribution and abundance of species across the three vegetation types present are largely influenced by these environmental gradients (edaphic abiotic factors and biotic (anthropogenic factors) as revealed in the present study. The absence of mangrove species in the other study sites reveals of their adaptation and dependence on increased moisture content and salinity which projects their possession of complex tissues that make them tolerant to such adverse factors in their environment. Whilst the complete absences of the rainforest species in the mangrove study sites also exposed their intolerance to saline conditions and high electrical conductivity as revealed from the soil analysis.

The mangal-tropical rainforest ecotone located in Asarama, Andoni is a natural formed ecotone possessing unique environmental condition, soil type and physiognomy. This can be attributed to the influence and interaction of the features and properties of the environmental gradient of the adjacent vegetation types. However, this ecotone can be regarded as upland / wetland ecotone because of its positioning between aquatic (mangrove) and upland (rainforest) vegetation types which corroborates a similar observation by Burk [79]. It is a transition zone between a high species rich community (rainforest) and a low species rich community (mangrove) rather than a blending zone because of the absence of equal number of species from both adjacent sites (55 species from the rainforest and 6 species from the mangrove sites as exemplified in Table 2). Furthermore, the tropical-mangal rainforest ecotone recorded 29 ecotonal species that were found only in the ecotone, mangrove (5 species) and rainforest (21 species). A major feature of the upland/wetland ecotone is the presence of high species diversity and richness due to its optimum moisture content, soil conditions and microclimate favourable to species not found on the adjacent sites giving rise to its ecotonal species (e.g. *Paspalum vaginatum, Chrysobalanus icaco* and *Acrosticum aureum*) [80]. Ecotonal species always record the highest abundance or frequency in an ecotone [81] in which *Paspalum vaginatum* recorded the highest in the tropical-mangal rainforest ecotone.

5. CONCLUSION

The mangal-tropical rainforest ecotone located in Asarama, Andoni is a natural formed ecotone possessing unique environmental condition, soil type and physiognomy. This can be attributed to the influence and interaction of the features and properties of the environmental gradient of the adjacent vegetation types. The various study sites has revealed some variation in their phytosociological and physicochemical assessment. However, the studied environmental gradients including salinity, pH, electrical conductivity, moisture content, organic matter and organic carbon have played major roles in the presence or absence of species in the three studied sites; with the ecotone study site recording the highest values in phytosociological assessment (species composition, abundance, frequency, density, species diversity and richness) and optimum levels in physicochemical assessment. Furthermore, the distribution and abundance of species across the three vegetation types present are largely influenced by these environmental gradients (edaphic abiotic factors and biotic (anthropogenic factors) as revealed in the present study. The absence of mangrove species in the ecotone and rainforest study sites reveals of their adaptation and dependence on increased moisture content and salinity which projects their possession of complex tissues that make them tolerant to such adverse factors in their environment. Whilst the complete absences of the rainforest species in the mangrove study sites also exposed their intolerance to saline conditions and high electrical conductivity as revealed from the soil analysis. Due to the species richness and diversity in the ecotone and ease of access to the other adjacent zones through it; there's a lot of ecological demand placed on it by humans leading to influencing its species composition and size. However, it can be deduced that the dissimilarity amongst the study sites can be attributed to the influence of the environmental gradients which is not limited to just abiotic factors but also anthropogenic factors.

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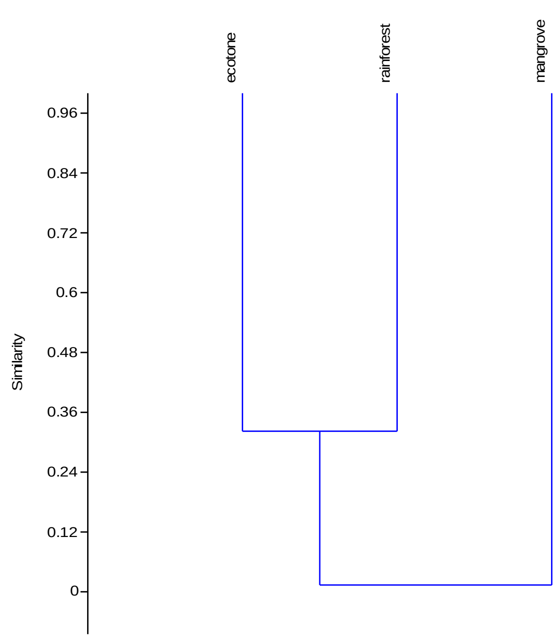

Table 2: Phytosociological frequency of sampled sites species prevalence in Asarama study sites.

S/N	SPECIES	FAMILY	MANGROVE	ECOTONE	RAINFOREST
1.	*Pteris acantonuera* Alston	Adiantaceae	-	+	-
2.	*Crinum jagus* (J. Thomps) Dandy	Amaryllidaceae	-	+	+
3.	*Lannea acida* A. Rich	Anacardiaceae	-	-	+
4	*Cleistopholis patens* (Benth.) Engl & Diels	Annonaceae	-	-	+
5	*Rauvolfia caffra* Sond.	Apocynacea	-	+	+
6	*Landolphia ovariensis* P. Beauv	Apocynaceae	-	+	-
7	*Funtumia africana* (Benth) Stapf	Apocynaceae	-	+	+
8	*Voacanga africana* Stapf	Apocynaceae	-	+	+
9	*Hederanthera barteri* (Hook F.) Pichan	Apocynaceae	-	+	+
10	*Rauvolfia vomitoria* Afzel.	Apocynaceae	-	-	+
11	*Alstonia congensis* Engl	Apocynaceae	-	-	+
12	*Elaeis guineensis* Jacq. E	Arecaceae	-	+	+
13	*Podococcus bateri* Mann& H. Wendl	Arecaceae	-	+	-
14	*Nypa fruticans* Wurmb	Arecaceae	+ **	+ **	+ **
15	*Laccosperma opacum* (G. Mann & H. Wendl) Drude	Arecaceae	-	-	+
16	*Eramospartha macrocarpa* Jacq	Arecaceae	-	+	+
17	*Podococcus bateri* Mann& H. Wendl	Arecaceae	-	-	+
18	*Laccosperma acutiflora* (P. Beauv.) Oktze	Arecaceae	-	-	+
19	*Culcasia scandens* P. Beauv	Arecaceae	-	-	+
20	*Avicenia germinans* (L.) L.	Avicenniaceae	+	-	-
21	*Canarium schweinfurthii* Eng.	Burseraceae	-	+	+
22	*Cleome rutidosperma* DC.	Capparaceae	-	-	+
23	*Musanga cecropoides* R. Br	Cecropiaceae	-	-	+
24	*Chrysobalanus icaco* (L.) L	Chrysobalanaceae	-	+	-
25	*Acioa barteri* (Hook. F) Engl	Chrysobalanaceae	-	+	-
26	*Combretum racemosum* P. Beauv	Combretaceae	-	+	+
27	*Conocarpus erectus* L.	Combretaceae	-	+	-
28	*Combretum hispidum* Laws	Combretaceae	-	+	+
29	*Laguncularia racemosa* (L.)C.F. Gaertn	Combretaceae	+	-	-
30	*Cynotis lanata* Benth.	Commelinaceae	-	-	+
31	*Fimbristylis littoralis* Gaud	Cyperaceae	-	+	+
32	*Fimbristylis ferruginea* (L.) Vahl	Cyperaceae	-	+	-

33	*Scleria verrucosa* Willd.	Cyperaceae	-	+	+
34	*Fuirena ciliaris* (L.) Roxb.	Cyperaceae	-	+	-
35	*Rhynchospora corymbosa* (L.) Britt	Cyperaceae	-	+	-
36	*Scleria naumanniana* Boeck	Cyperaceae	-	+	+
37	*Hypolytrum heterophorphum* Nelmes	Cyperaceae	-	+	+
38	*Cyperus* sp	Cyperaceae	-	+	-
39	*Fuirena umbellata* Rottb.	Cyperaceae	-	+	-
40	*Tetracera alnifolia* Willd.	Dilleniaceae	-	+	+
41	*Draceana arborea* (Willd) Link	Draceanaceae	-	+	+
42	*Alchornea laxiflora* (Benth.)Pax & K. Hoffm	Euphorbiaceae	-	+	-
43	*Alchornea cordifolia* (Schumach & Thonn.) Mull. Arg.	Euphorbiaceae	-	+	+
44	*Maesobotrya dusenii* (Pax)Hutch.	Euphorbiaceae	-	+	-
45	*Maesobotrya barteri* (Baill.) Hutch	Euphorbiaceae	-	+	-
46	*Phyllantus* sp.	Euphorbiaceae	-	-	+
47	*Delbergia ecastaphyllum* (L.) Taub	Fabaceae	-	+	+
48	*Dalbergia heudelotii* Staph.	Fabaceae	-	+	-
49	*Machaerum lunatum* (Lf.) Ducke	Fabaceae	-	+	-
50	*Harungana madasgascariensis* Lam ex Poiret	Guttiferae	-	+	+
51	*Hyptis lanceolata* Poir	Lamiaceae	-	+	-
52	*Anthocleista liebrechtsiana* De Wild & T Durand	Loganiaceae	-	+	+
53	*Anthocleista nobilis* G. Don	Loganiaceae	-	+	+
54	*Anthocleista vogelii* Planch	Loganiaceae	-	+	-
55	*Anthocleista djalonensis* A. Chev	Loganiaceae	-	+	+
56	*Spigelia anthelmia* Linn.	Loganiaceae	-	-	+
57	*Marattia fraxinea* Sm	Marrattiaceae	-	+	-
58	*Heterotis rotundifolia* (Sm.) Jacq. Fel	Melastomataceae	-	+	+
59	*Melastomastrum capitatum* (Vahl) A & R Fernandes	Melastomataceae	-	+	+
60	*Osbeckia tubulosa* Sm.	Melastomataceae	-	+	-
61	*Ficus sagittifolia* Warb. ex MildBr. Burret	Moraceae	-	+	-
62	*Ficus polita* Vahl	Moraceae	-	+	+
63	*Ficus sur* Forskk	Moraceae	-	+	+
64	*Ficus asperifolia* Mig	Moraceae	-	+	-
65	*Syzygium guineensi* (Willd.) DC	Myrtaceae	-	+	-
66	*Lophira alata* Banks ex Gaertn	Ochnaceae	-	+	-
67	*Barteria nigritana* Hook f.	Passifloraceae	-	+	-

68	*Smithmania pubescence* Soland.	Passifloraceae	-	-	+
69	*Passiflora foetida* L.	Passifloraceae	-	-	+
70	*Paspalum vaginatum* Sw.	Poaceae	-	+	-
71	*Oplismenus burmanii* (Retz) P. Beauv	Poaceae	-	-	+
72	*Carpolobia lutea* G. Don	Polygalaceae	-	+	+
73	*Pycreus lanceolata* (L.) Farw.	Polypodiaceae	-	+	-
74	*Phymatode scolopendria* (Burm. F.) Pic. Serm	Polypodiaceae	-	+	-
75	*Acrostichum aureum* L.	Adiantaceae	-	+	+
76	*Rhizophora racemosa* G.Mey	Rhizophoraceae	+	-	-
77	*Rhizophora mangle* L.	Rhizophoraceae	+	-	-
78	*Rhizophora harizonii* Leechman	Rhizophoraceae	+	-	-
79	*Sabicea geophiloides* Wernham	Rubiaceae	-	+	+
80	*Craterispermum caudatum* Hutch.	Rubiaceae	-	+	-
81	*Nauclea latifolia* Sm.	Rubiaceae	-	-	+
82	*Hellea leadermanii* (K. Krause)Verde	Rubiaceae	-	-	+
83	*Massalaria accuminata* (G. Don) Bullock	Rubiaceae	-	-	+
84	*Manilkara obovata* (Sabine & G. Don) J. H. Hemsi	Sapotaceae	-	-	+
85	*Lygodium smithianium* Presl.	Schizaeaceae	-	+	+
86	*Lygodium microphyllum* (Cav.) R.Br	Schizaeeceae	-	+	+
87	*Selaginella myosurus* Alston	Selaginellaceae	-	+	+
88	*Thelypteris bargiana* (Schlect.) Ching	Thelypteridaceae	-	+	-
89	*Stachytarpheta cayennesis* (Rich)Vahl	Verbanaceae	-	-	+
90	*Vitex doniana* Sweet.	Verbenaceae	-	+	+
	TOTAL No. of Species frequency		**6**	**64**	**55**

Note: (+) Presence; (-) Absence
(**): Common species & family in the three study sites

Table 3: Floristic Composition of the Sampled Site Species Density (Individual No. of Species).

S/No	Species	Family	Life Form	Mangrove	Ecotone	Rainforest
1.	*Musanga cecropoides* R. Br	Cecropiaceae	Megaphanerophyte	-	-	3
2.	*Ficus polita* Vahl	Moraceae	Megaphanerophyte	-	3	1
3.	*Lannea acida* A. Rich	Anacardiaceae	Megaphanerophyte	-	-	1
4	*Cleistopholis patens* (Benth.) Engl & Diels	Annonaceae	Megaphanerophyte	-	-	2
5	*Rauvolfia vomitoria* Afzel.	Apocynaceae	Megaphanerophyte	-	-	3
6	*Alstonia congensis* Engl	Apocynaceae	Megaphanerophyte	-	-	2
7	*Elaeis guineensis* Jacq. E	Aracaceae	Megaphanerophyte	-	22	9
8	*Canarium schweinfurthii* Eng.	Burseraceae	Megaphanerophyte	-	6	3
9	*Anthocleista liebrechtsiana* De Wild & T Durand	Loganiaceae	Megaphanerophyte	-	12	7
10	*Anthocleista nobilis* G. Don	Loganiaceae	Megaphanerophyte	-	18	**41****
11	*Anthocleista vogelii* Planch	Loganiaceae	Megaphanerophyte	-	17	-
12	*Anthocleista djalonensis* A. Chev	Loganiaceae	Megaphanerophyte	-	4	6
13	*Ficus sur* Forskk	Moraceae	Megaphanerophyte	-	4	2
14	*Lophira alata* Banks ex Gaertn	Ochnaceae	Megaphanerophyte	-	2	-
15	*Rhizophora racemosa* G.Mey	Rhizophoraceae	Megaphanerophyte	25	-	-
16	*Rhizophora mangle* L.	Rhizophoraceae	Megaphanerophyte	6	-	-
17	*Hellea leadermanii* (K. Krause)Verde	Rubiaceae	Megaphanerophyte	-	-	7
18	*Avicenia germinans* (L.) L.	Avicenniaceae	Megaphanerophyte	8	-	-
19	*Rauvolfia caffra* Sond.	Apocynaceae	Mesophanerophyte	-	4	2
20	*Funtumia africana* (Benth) Stapf	Apocynaceae	Mesophanerophyte	-	7	2
21	*Voacanga africana* Stapf	Apocynaceae	Mesophanerophyte	-	3	4
22	*Hederanthera barteri* (Hook F.) Pichan	Apocynaceae	Mesophanerophyte	-	8	5
23	*Nypa fruticans* Wurmb	Arecaceae	Mesophanerophyte	**58 ****	22	1
24	*Laccosperma opacum* (G. Mann & H. Wendl) Drude	Arecaceae	Mesophanerophyte	-	-	10
25	*Laccosperma acutiflora* (P. Beauv.) Oktze	Arecaceae	Mesophanerophyte	-	-	22
26	*Chrysobalanus icaco* (L.) L	Chrysobalanaceae	Mesophanerophyte	-	43	-
27	*Acioa barteri* (Hook. F) Engl	Chrysobalanaceae	Mesophanerophyte	-	8	-
28	*Conocarpus erectus* L.	Combretaceae	Mesophanerophyte	-	13	-

29	*Draceana arborea* (Willd) Link	Draceanaceae	Mesophanerophyte	-	5	2
30	*Laguncularia racemosa* (L.)C.F. Gaertn	Combretaceae	Mesophanerophyte	12	-	-
31	*Alchornea laxiflora* (Benth.)Pax & K. Hoffm	Euphorbiaceae	Mesophanerophyte	-	2	-
32	*Alchornea cordifolia* (Schumach & Thonn.) Mull. Arg.	Euphorbiaceae	Mesophanerophyte	-	10	9
33	*Maesobotrya dusenii* (Pax)Hutch.	Euphorbiaceae	Mesophanerophyte	-	3	-
34	*Maesobotrya barteri* (Baill.) Hutch	Euphorbiaceae	Mesophanerophyte	-	2	-
35	*Machaerum lunatum* (Lf.) Ducke	Fabaceae	Mesophanerophyte	-	7	-
36	*Harungana madasgascariensis* Lam ex Poiret	Guttiferae	Mesophanerophyte	-	16	4
37	*Melastomastrum capitatum* (Vahl) A & R Fernandes	Melastomataceae	Mesophanerophyte	-	25	8
38	*Osbeckia tubulosa* Sm.	Melastomataceae	Mesophanerophyte	-	10	-
39	*Ficus sagittifolia* Warb. ex MildBr. Burret	Moraceae	Mesophanerophyte	-	1	-
40	*Ficus asperifolia* Mig	Moraceae	Mesophanerophyte	-	3	-
41	*Syzygium guineensi* (Willd.) DC	Myrtaceae	Mesophanerophyte	-	25	-
42	*Barteria nigritana* Hook f.	Passifloraceae	Mesophanerophyte	-	9	-
43	*Smithmania pubescence* Soland.	Passifloraceae	Mesophanerophyte	-	-	2
44	*Carpolobia lutea* G. Don	Polygalaceae	Mesophanerophyte	-	13	5
45	*Rhizophora harizonii* Leechman	Rhizophoraceae	Mesophanerophyte	12	-	-
46	*Craterispermum caudatum* Hutch.	Rubiaceae	Mesophanerophyte	-	7	-
47	*Nauclea latifolia* Sm.	Rubiaceae	Mesophanerophyte	-	-	2
48	*Massularia accuminata* (G. Don) Bullock	Rubiaceae	Mesophanerophyte	-	-	3
49	*Manilkara obovata* (Sabine & G. Don) J. H. Hemsi	Sapotaceae	Mesophanerophyte	-	-	4
50	*Stachyarpheta cayennesis* (Rich)Vahl	Verbanaceae	Mesophanerophyte	-	-	5
51	*Vitex doniana* Sweet.	Verbenaceae	Mesophanerophyte	-	12	5
52	*Culcasia scandens* P. Beauv	Arecaceae	Microphanerophyte	-	-	7
53	*Oplismenus burmanii* (Retz) P. Beauv	Poaceae	Microphanerophyte	-	-	25
54	*Pteris acantonuera* Alston	Adiantaceae	Microphanerophyte	-	8	-
55	*Crinum jagus* (J. Thomps) Dandy	Amaryllidaceae	Microphanerophyte	-	18	16
56	*Landolphia ovariensis* P. Beauv	Apocynaceae	Microphanerophyte	-	28	-

57	*Podococcus bateri* Mann& H. Wendl	Aracaceae	Microphanerophyte	-	5	-
58	*Eramospartha macrocarpa* Jacq	Arecaceae	Microphanerophyte	-	8	10
59	*Podococcus bateri* Mann& H. Wendl	Arecaceae	Microphanerophyte	-	-	13
60	*Cleome rutidosperma* DC.	Capparaceae	Microphanerophyte	-	-	5
61	*Combretum racemosum* P. Beauv	Combretaceae	Microphanerophyte	-	4	5
62	*Combretum hispidum* Laws	Combretaceae	Microphanerophyte	-	20	12
63	*Cynotis lanata* Benth.	Commelinaceae	Microphanerophyte	-	-	30
64	*Fimbristylis littoralis* Gaud	Cyperaceae	Microphanerophyte	-	**180** **	10
65	*Fimbristylis ferruginea* (L.) Vahl	Cyperaceae	Microphanerophyte	-	20	-
66	*Scleria verrucosa* Willd.	Cyperaceae	Microphanerophyte	-	34	19
67	*Fuirena ciliaris* (L.) Roxb.	Cyperaceae	Microphanerophyte	-	25	-
68	*Rhynchospora corymbosa* (L.) Britt	Cyperaceae	Microphanerophyte	-	15	-
69	*Scleria naumanniana* Boeck	Cyperaceae	Microphanerophyte	-	62	20
70	*Hypolytrum heterophorphum* Nelmes	Cyperaceae	Microphanerophyte	-	19	6
71	*Cyperu*s sp	Cyperaceae	Microphanerophyte	-	25	-
72	*Fuirena umbellata* Rottb.	Cyperaceae	Microphanerophyte	-	10	-
73	*Tetracera alnifolia* Willd.	Dilleniaceae	Microphanerophyte	-	65	**35** **
74	*Phyllantus* sp.	Euphorbiaceae	Microphanerophyte	-	-	2
75	*Delbergia ecastaphyllum* (L.) Taub	Fabaceae	Microphanerophyte	-	75	1
76	*Dalbergia heudelotii* Staph.	Fabaceae	Microphanerophyte	-	20	-
77	*Hyptis lanceolata* Poir	Lamiaceae	Microphanerophyte	-	40	-
78	*Spigelia anthelmia* Linn.	Loganiaceae	Microphanerophyte	-	-	8
79	*Marattia fraxinea* Sm	Marrattiaceae	Microphanerophyte	-	23	-
80	*Heterotis rotundifolia* (Sm.) Jacq. Fel	Melastomataceae	Microphanerophyte	-	15	30
81	*Passiflora foetida* L.	Passifloraceae	Microphanerophyte	-	-	6
82	*Paspalum vaginatum* Sw.	Poaceae	Microphanerophyte	-	**175** **	-
83	*Pycreus lanceolata* (L.) Farw.	Polypodiaceae	Microphanerophyte	-	75	-
84	*Phymatode scolopendria* (Burm. F.) Pic. Serm	Polypodiaceae	Microphanerophyte	-	15	-
85	*Acrostichum aureum* L.	Adiantaceae	Microphanerophyte	-	25	1
86	*Sabicea geophiloides* Wernham	Rubiaceae	Microphanerophyte	-	80	32
87	*Lygodium smithuanum* Presl.	Schizaeaceae	Microphanerophyte	-	45	**51** **

88	*Lygodium microphyllum* (Cav.) R.Br	Schizaeeceae	Microphanerophyte	-	85	15
89	*Selaginella myosorus* Alston	Selaginellaceae	Microphanerophyte	-	75	30
90	*Thelypteris bargiana (Schlect.) Ching*	Thelypteridaceae	Microphanerophyte	-	20	-
	Total No. Of Individual Species (ha^{-1})			**121**	**1660**	**574**
	Most Dominant Species			**	**	**

Table 4: Phytosociology of the Mangrove study site

S/N	SPECIES	FAMILY	Common name	Habit	%F	A	D	%RF	%RA	%RD	IVI	RIVI	SdH'	SdE	DmgR	A/F	Remark
1	*Nypa fruticans* Wurmb	Arecaceae	Nypa palm	Shrub	40	29.00	11.60	11.76	58.00	47.93	117.69	39.90	62.66	80.52	3.79	0.73	++
2	*Avicenia germinans* (L) L.	Avicenniaceae	White mangrove	Tree	60	2.67	1.60	17.65	5.34	6.61	29.60	9.88	9.83	12.63	3.79	0.05	+++
3	*Laguncularia racemosa* (L) C. F. Gaertn	Combretaceae	Black mangrove	Shrub	60	4.00	2.40	17.65	8.00	9.92	35.57	11.88	12.77	16.41	3.79	0.07	+++
4	*Rhizophora racemosa* L.	Rhizophoraceae	Red mangrove	Tree	60	8.33	5.00	17.65	16.66	20.66	54.97	18.36	23.20	29.82	3.79	0.14	+++
5	*Rhizophora mangle* L.	Rhizophoraceae	Red mangrove	Tree	40	3.00	1.20	11.76	6.00	4.96	22.72	7.59	6.68	8.59	3.79	0.08	++
6	*Rhizophora harizonii* Leechman	Rhizophoraceae	Red mangrove	Tree	80	3.00	2.40	23.53	6.00	9.92	39.45	13.17	14.74	18.95	3.79	0.04	++++
	TOTAL				**340**	**50.00**	**24.20**	**100.00**	**100.00**	**100.00**	**300.00**	**100.18**	**129.88**	**166.92**	**3.79**	**1.11**	

Note: %F = Percentage Frequency. D = Density (No. of individuals ha^{-1}). A=Abundance. %RF = Relative Frequency. %RD = Relative Density. %RA = Relative Abundance. IVI = Importance Value Index. DmgR = Margalef Species Richness. SdH' = Species Diversity. SdE =Species Diversity Evenness. A/F = Ratio A: F distribution pattern with the "thumb of rule" designated as follows: Regular (< 0.03), Random (0.03-0.05) and Contiguous (> 0.05) distribution. + (1-25) Very Scarce,+ (26-29) Scarce, +++ (60-79) Abundant, ++++> (80-α) Very Abundant.

Table 5: Phytosociology of the Ecotone study site

S/N	SPECIES	FAMILY	Common name	Habit	%F	A	D	%RF	%RA	%RD	IVI	RIVI	SdH’	SdE	DmgR	A:F	Remark
1.	*Pteris acantonuera* Alston	Adiantaceae	Fern	Herb	20	8.00	1.60	0.78	1.01	0.43	2.21	0.76	-0.09	-0.05	25.81	0.40	+
2.	*Crinum jagus* (J. Thomps) Dandy	Amaryllidaceae	Spider lily	Herb	40	9.00	36.00	1.55	1.14	0.99	3.66	1.27	0.13	0.07	25.81	0.23	++
3.	*Rauvolfia caffra* Sond.	Apocynacea	Quinine tree	Shrub	40	2.00	0.80	1.55	0.25	0.22	2.02	0.70	-0.11	-0.06	25.81	0.05	++
4	*Landolphia ovariensis* P. Beauv	Apocynaceae	Woody vine	Shrub	40	14.00	5.60	1.55	1.77	1.54	4.86	1.67	0.36	0.21	25.81	0.35	++
5	*Funtumia africana* (Benth) Stapf	Apocynaceae	False rubber plant	Shrub	20	7.00	1.40	0.78	0.88	0.39	2.04	0.71	-0.11	-0.06	25.81	0.35	+
6	*Voacanga africana* Stapf	Apocynaceae	N/A	Shrub	20	3.00	0.60	0.78	0.38	0.17	1.32	0.46	-0.16	-0.09	25.81	0.15	+
7	*Hederanthera barteri* (Hook F.) Pichan	Apocynaceae	N/A	Shrub	20	8.00	1.60	0.78	1.01	0.43	2.21	0.76	-0.09	-0.05	25.81	0.40	+
8	*Elaeis guineensis* Jacq. E	Aracaceae	Oilpalm tree	Tree	40	11.00	4.40	1.55	1.39	1.21	4.15	1.43	0.22	0.12	25.81	0.28	++
9	*Podococcus bateri* Mann& H. Wendl	Aracaceae	N/A	Herb	20	5.00	1.00	0.78	0.63	0.28	1.68	0.58	-0.14	-0.08	25.81	0.25	+
10	*Nypa fruticans* Wurmb	Arecacea	Nypa palm	Shrub	100	4.40	4.40	3.88	0.56	1.21	5.64	1.94	0.56	0.31	25.81	0.44	+++++
11	*Eramospartha macrocarpa* Jacq	Arecaceae	Palm	Herb	20	8.00	1.60	0.78	1.01	0.43	2.21	0.76	-0.09	-0.05	25.81	0.40	+
12	*Canarium schweinfurthii* Eng.	Burseraceae	Incense tree	Tree	40	3.00	1.20	1.55	0.38	0.33	2.26	0.78	-0.08	-0.05	25.81	0.08	++
13	*Chrysobalanus icaco* (L.) L	Chrysobalanaceae	Coco plum	Shrub	60	14.33	8.60	2.33	1.81	3.36	7.50	2.59	1.07	0.59	25.81	0.24	+++
14	*Acioa barteri* (Hook. F) Engl	Chrysobalanaceae	N/A	Shrub	20	8.00	1.60	0.78	1.01	0.43	2.21	0.76	-0.09	-0.05	25.81	0.40	+
15	*Combretum racemosum* P. Beauv	Combretaceae	English Christmas plant	Herb	20	4.00	0.80	0.78	0.51	0.22	1.50	0.52	-0.15	-0.08	25.81	0.20	+
16	*Conocarpus erectus* L.	Combretaceae	Button wood	Shrub	40	6.50	2.60	1.55	0.82	0.72	3.09	1.06	0.03	0.16	25.81	0.16	++
17	*Combretum hispidum* Laws	Combretaceae	N/A	Herb	40	10.00	4.00	1.55	1.26	1.10	3.91	1.35	0.18	0.10	25.81	0.25	++
18	*Fimbristylis littoralis* Gaud	Cyperaceae	Sedge	Herb	80	45.00	36.00	3.10	5.68	9.90	18.67	6.44	5.21	2.87	25.81	0.56	++++
19	*Fimbristylis ferruginea* (L.) Vahl	Cyperaceae	Sedge	Herb	20	20.00	4.00	0.78	2.52	1.10	4.40	1.52	0.28	0.15	25.81	1.00	+
20	*Scleria verrucosa* Willd.	Cyperaceae	Sedge Bush knife	Herb	80	8.50	6.80	3.10	1.07	1.87	6.04	2.08	0.67	0.37	25.81	0.11	++++
21	*Fuirena ciliaris* (L.) Roxb.	Cyperaceae	Sedge	Herb	20	25.00	5.00	0.78	3.15	1.37	5.30	1.83	0.48	0.27	25.81	1.25	+
22	*Rhynchospora corymbosa* (L.) Britt	Cyperaceae	Sedge	Herb	20	15.00	3.00	0.78	1.89	0.83	3.49	1.20	0.10	0.05	25.81	0.75	+
23	*Scleria naumanniana* Boeck	Cyperaceae	Sedge Bush knife	Herb	80	15.50	12.40	3.10	0.15	3.41	6.66	2.30	0.83	0.46	25.81	0.19	++++
24	*Hypolytrum heterophorphum* Nelmes	Cyperaceae	Sedge	Herb	40	9.50	3.80	1.55	1.20	1.05	3.79	1.31	0.15	0.08	25.81	0.24	++
25	*Cyperus* sp	Cyperaceae	Sedge	Herb	20	25.00	5.00	0.78	3.15	1.37	5.30	1.83	0.48	0.27	25.81	1.25	+
26	*Fuirena umbellata* Rottb.	Cyperaceae	Sedge	Herb	20	10.00	2.00	0.78	1.26	0.54	2.58	0.89	-0.05	-0.03	25.81	0.50	+

27	*Pycreus lanceolatus* (Poir.) C.B.Cl.	Cyperaceae		Herb	40	37.50	15.00	1.55	4.73	4.12	10.40	3.59	1.20	1.10	25.81	0.94	++
28	*Tetracera alnifolia* Willd.	Dilleniaceae	Liane cord	Herb	80	16.25	13.00	3.10	2.05	3.57	8.72	3.01	1.44	0.79	25.81	0.20	++++
29	*Draceana arborea* (Willd) Link	Draceanaceae	Asparagus plant	Shrub	40	2.50	1.00	1.55	0.32	0.28	2.14	0.74	-0.10	-0.05	25.81	0.06	++
30	*Alchornea laxiflora* (Benth.)Pax & K. Hoffm	Euphorbiaceae	Christmas bush	Shrub	20	2.00	0.40	0.78	0.25	0.11	1.14	0.39	-0.16	-0.09	25.81	0.10	+
31	*Alchornea cordifolia* (Schumach & Thonn.) Mull. Arg.	Euphorbiaceae	Christmas bush	Shrub	40	5.00	2.00	1.55	0.63	0.31	2.50	0.86	-0.06	-0.03	25.81	0.13	++
32	*Maesobotrya dusenii* (Pax) Hutch.	Euphorbiaceae	Red Bush cherry	Shrub	20	3.00	0.60	0.78	0.38	0.17	1.32	0.46	-0.16	-0.09	25.81	0.15	+
33	*Maesobotrya barteri* (Baill.) Hutch	Euphorbiaceae	White Bush cherry	Shrub	20	2.00	0.40	0.78	0.25	0.11	1.14	0.39	-0.16	-0.09	25.81	0.10	+
34	*Delbergia ecastaphyllum* (L.) Taub	Fabaceae	Coin vine	Herb	60	25.00	15.00	2.33	3.15	4.12	9.60	3.31	1.72	0.95	25.81	0.42	+++
35	*Dalbergia heudelotii* Staph.	Fabaceae	Coin vine	Herb	40	10.00	4.00	1.55	1.26	1.10	3.91	1.35	0.18	0.10	25.81	0.25	++
36	*Machaerum lunatum* (Lf.) Ducke	Fabaceae	N/A	Shrub	20	7.00	1.40	0.76	0.88	0.39	2.04	0.71	-0.11	-0.06	25.81	0.35	+
37	*Harrungana madasgascariensis* Lam ex Poiret	Guttiferae	Dragon’s blood	Shrub	20	16.00	3.20	0.78	2.02	0.87	3.66	1.26	0.13	0.07	25.81	0.80	+
38	*Hyptis lanceolata* Poir	Labiateceae	Kolocum	Herb	40	20.00	8.00	1.55	2.52	2.20	6.27	2.16	0.73	0.40	25.81	0.50	++
39	*Anthocliesta liebrechtsiana* De Wild & T Durand	Loganiaceae	Cabbage tree	Tree	100	2.40	2.40	3.88	0.30	0.66	4.84	1.67	0.37	0.21	25.81	0.02	+++++
40	*Anthocliesta nobilis* G. Don	Loganiaceae	Cabbage tree	Tree	60	6.00	3.60	2.33	0.76	0.99	4.07	1.41	0.21	0.11	25.81	0.10	+++
41	*Anthocliesta vogelii* Planch	Loganiaceae	Cabbage tree	Tree	60	5.67	3.40	2.33	0.72	0.94	3.98	1.37	0.19	0.10	25.81	0.10	+++
42	*Anthocliesta djalonensis* A. Chev	Loganiaceae	Cabbage tree	Tree	20	4.00	0.80	0.78	0.51	0.22	1.50	0.52	-0.15	-0.08	25.81	0.20	+
43	*Marattia fraxinea* Sm	Marrattiaceae	Fern	Herb	40	11.50	4.60	1.55	1.45	1.26	4.27	1.47	0.25	0.14	25.81	0.29	++
44	*Heterotis rotundifolia* (Sm.) Jacq. Fel	Melastomataceae	Cheek weed	Herb	20	15.00	3.00	0.78	1.89	0.83	3.49	1.20	0.10	0.05	25.81	0.75	+
45	*Melastomastrum capitatum* (Vahl) A & R Fernandes	Melastomataceae	N/A	Herb	20	25.00	5.00	0.78	3.15	1.37	5.30	1.83	0.48	0.26	25.81	1.25	+
46	*Osbeckia tubulosa* Sm.	Melastomataceae	N/A	Shrub	20	10.00	2.00	0.78	1.26	0.54	2.58	0.89	-0.05	-0.03	25.81	0.50	+
47	*Ficus sagittifolia* Warb. ex MildBr. Burret	Moraceae	Fig tree	Shrub	20	1.00	0.20	0.78	0.13	0.06	0.96	0.32	-0.16	-0.09	25.81	0.05	++
48	*Ficus polita* Vahl	Moraceae	Fig. tree	Shrub	40	1.50	0.60	1.55	1.20	0.17	1.90	0.66	-0.12	-0.07	25.81	0.04	++
49	*Ficus sur* Forskk	Moraceae	Fig. tree	Tree	40	2.00	0.80	1.55	0.25	0.21	2.01	0.69	-0.11	-0.06	25.81	0.05	++
50	*Ficus asperifolia* Mig	Moraceae	Fig. tree	Shrub	20	3.00	0.60	0.78	0.38	0.17	1.32	0.46	-0.16	-0.09	25.81	0.15	+
51	*Syzygium guineensi* (Willd.) DC	Myrtaceae	Water berry	Shrub	60	8.33	5.00	2.33	1.05	1.37	4.75	1.64	0.35	0.19	25.81	0.14	+++
52	*Lophira alata* Banks ex Gaertn	Ochnaceae	Iron wood	Tree	20	2.00	0.40	0.78	0.25	0.11	1.14	0.39	-0.16	-0.09	25.81	0.10	+

53	*Barteria nigritana* Hook f.	Passifloraceae	N/A	Shrub	60	3.00	1.80	2.33	0.38	0.50	3.20	1.10	0.05	0.03	25.81	0.05	+++
54	*Paspalum vaginatum* Sw.	Poacea	Silt grass	Herb	60	58.33	35.00	2.33	7.36	9.62	19.31	6.66	5.48	3.02	25.81	0.97	+++
55	*Carpolobia lutea* G. Don	Polygalaceae	Poor man's candle stick	Shrub	40	6.50	2.60	1.55	0.81	0.72	3.08	1.06	0.03	0.02	25.81	0.16	++
56	*Phymatode scolopendria* (Burm. F.) Pic. Serm	Polypodiaceae	Fern	Herb	40	7.50	2.40	1.55	0.95	0.66	3.16	3.51	1.91	1.06	25.81	0.19	++
57	*Acrostichum auruem* L.	Pteridaceae	Aquatic fern	Herb	100	5.00	5.00	3.88	0.63	1.37	5.88	2.03	0.62	0.34	25.81	0.05	+++++
58	*Sabicea geophiloides* Wernham	Rubiaceae	N/A	Herb	40	40.00	16.00	1.55	5.05	4.40	10.99	3.79	2.20	1.21	25.81	1.00	++
59	*Craterispermum caudatum* Hutch.	Rubiaceae	Chewing Stick	Shrub	20	7.00	1.40	0.78	0.88	0.39	2.04	0.71	-0.11	-0.06	25.81	0.35	+
60	*Lygodium smithianium* Presl.	Schizaeaceae	Fern	Herb	60	15.00	9.00	2.33	1.89	2.47	6.69	2.31	0.84	0.46	25.81	0.25	+++
61	*Lygodium microphyllum* (Cav.) R.Br	Schizaeeceae	Fern	Herb	100	17.00	17.00	3.88	2.15	4.67	10.69	3.69	2.09	1.15	25.81	0.17	+++++
62	*Selaginella myosurus* Alston	Selaginellaceae	Fern	Herb	20	75.00	15.00	0.78	9.46	4.12	14.36	4.95	3.44	1.20	25.81	3.75	+
63	*Thelypteris bargiana* (Schlect.) Ching	Thelypteridaceae	Fern	Herb	40	10.00	4.00	1.55	1.26	1.10	3.91	1.35	0.18	0.10	25.81	0.25	++
64	*Vitex doniana* Sweet.	Verbenaceae	Black plum	Shrub	40	6.00	2.40	1.55	0.76	0.66	2.97	1.02	0.01	0.06	25.81	0.15	++
	TOTAL				**2580**	**792.71**	**363.8**	**100.15**	**99.21**	**91.83**	**289.96**	**102.43**	**32.02**	**17.57**	**25.81**	**25.56**	

Note: %F = Percentage Frequency. D = Density (No. of individuals ha^{-1}). A=Abundance. %RF = Relative Frequency. %RD = Relative Density. %RA = Relative Abundance. IVI = Importance Value Index. DmgR = Margalef Species Richness. SdH' = Species Diversity. SdE =Species Diversity Evenness. A/F = Ratio A: F distribution pattern with the "thumb of rule" designated as follows: Regular (< 0.03), Random (0.03-0.05) and Contiguous (> 0.05) distribution. + (1-25) Very Scarce,+ (26-29) Scarce, +++ (60-79) Abundant, ++++> (80-α) Very Abundant, NA – Not Available.

Table 6: Phytosociology of the Rainforest study site

S/N	SPECIES	FAMILY	Common name	Habit	%F	A	D	%RF	%RA	%RD	IVI	R IVI	SdH'	*SdE*	Dmg R	A:F	Remark
1.	*Crinum jagus* (J. Thomps) Dandy	Amaryllidaceae	Spider lily	Herb	40	8.00	3.20	2.15	2.37	2.83	7.34	2.40	0.92	0.53	24.99	0.20	++
2.	*Lannea acida* A. Rich	Anacardiaceae	N/A	Tree	20	1.00	0.20	1.08	0.30	0.18	1.55	0.51	-0.15	-0.09	24.99	0.05	+
3.	*Cleistopholis patens* (Benth.) Engl & Diels	Annonaceae	Salt &oil plant	Tree	20	2.00	0.40	1.08	0.59	0.35	2.03	0.66	-0.12	-0.07	24.99	0.10	+
4	*Hederanthera barteri* (Hook F.) Pichan	Apocynaceae	N/A	Shrub	20	5.00	1.00	1.08	1.48	0.88	4.44	1.45	0.24	0.14	24.99	0.25	+
5	*Rauvolfia vomitoria* Afzel.	Apocynaceae	Swizzle stick	Shrub	40	1.50	0.60	2.15	0.44	0.53	3.12	1.02	0.01	0.01	24.99	0.04	++

6	*Rauvolfia caffra* Sond.	Apocynaceae	Quinine tree	Shrub	20	2.00	0.40	1.08	0.59	0.35	2.03	0.66	-0.12	- 0.07	24.99	0.10	+
7	*Voacanga africana* Stapf	Apocynaceae	N/A	Shrub	40	2.00	0.80	2.15	0.59	0.71	3.45	1.13	0.06	0.03	24.99	0.05	++
8	*Funtumia africana* (Benth) Stapf	Apocynaceae	False rubber plant	Shrub	20	2.00	0.40	1.08	0.59	0.35	2.03	0.66	-0.12	- 0.07	24.99	0.10	+
9	*Alstonia congensis* Engl	Apocynaceae	Pattern wood	Tree	20	2.00	0.40	1.08	0.59	0.35	2.025	0.66	-0.12	- 0.07	24.99	0.10	+
10	*Podococcus bateri* Mann& H. Wendl	Aracaceae	N/A	Herb	60	4.33	2.60	3.23	1.28	2.30	6.81	2.23	0.78	0.45	24.99	0.07	+++
11	*Elaeis guineensis* Jacq. E	Aracaceae	Oilpalm tree	Tree	60	3.00	1.80	3.23	0.89	1.59	5.71	1.87	0.51	0.29	24.99	0.05	+++
12	*Nypa fruticans* Wurmb	Aracaceae	Nypa palm	Shrub	20	1.00	0.20	1.08	0.30	0.18	1.55	0.51	-0.15	- 0.09	24.99	0.05	+
13	*Culcasia scandens* P. Beauv	Aracaceae	Climbing arum	Herb	40	3.50	1.40	2.15	1.04	1.24	4.42	1.45	0.23	0.13	24.99	0.09	++
14	*Laccosperma opacum* (G. Mann & H. Wendl) Drude	Arecaceae	Rattan palm	Shrub	40	5.00	2.00	2.15	1.48	1.77	7.56	2.47	0.97	0.56	24.99	0.13	++
15	*Eramospartha macrocarpa* Jacq	Arecaceae	Palm	Herb	40	5.00	2.00	2.15	1.48	1.77	5.40	1.77	0.44	0.25	24.99	0.13	++
16	*Laccosperma acutiflora* (P. Beauv.) Oktze	Arecaceae	Rattan palm	Shrub	60	7.33	4.40	3.23	2.17	3.89	9.29	3.04	1.47	1.33	24.99	0.12	+++
17	*Canarium schweinfurthii* Eng.	Burseraceae	Incense tree	Tree	40	1.50	0.60	2.15	0.44	0.53	3.12	1.02	0.01	- 0.07	24.99	0.04	++
18	*Cleome rutidosperma* DC.	Capparaceae	Fringe spider flower	Herb	20	5.00	1.00	1.08	1.48	0.88	3.44	1.13	0.06	0.03	24.99	0.25	+
19	*Musanga cecropoides* R. Br	Cecropiaceae	Umbrella tree	Tree	40	1.50	0.60	2.15	0.44	0.53	3.12	1.02	0.01	0.01	24.99	0.04	++
20	*Combretum racemosum* P. Beauv	Combretaceae	English Christmas plant	Herb	20	5.00	1.00	1.08	1.48	0.88	3.44	1.13	0.06	0.03	24.99	0.25	+
21	*Combretum hispidum* Laws	Combretaceae	N/A	Herb	20	12.00	2.40	1.08	3.55	2.12	6.75	2.22	0.77	0.44	24.99	0.60	+
22	*Cyanotis lanata* Benth.	Commelinaceae	N/A	Herb	40	15.00	6.00	2.15	4.44	5.30	11.89	3.89	2.30	1.33	24.99	0.38	++
23	*Fimbristylis littoralis* Gaud	Cyperaceae	Sedge	Herb	20	10.00	2.00	1.08	3.00	1.77	5.81	1.90	0.53	0.31	24.99	0.50	+
24	*Scleria verrucosa* Willd.	Cyperaceae	Bush knife	Herb	40	9.50	3.80	2.15	2.81	3.36	8.32	2.72	1.19	0.68	24.99	0.24	++
25	*Scleria naumanniana* Boeck	Cyperaceae	Bush knife	Herb	40	10.00	4.00	2.15	2.96	3.53	8.64	2.83	1.28	0.74	24.99	0.25	++
26	*Hypolytrum heteromorporphum* Nelmes	Cyperaceae	Sedge	Herb	20	6.00	1.20	1.08	1.78	1.06	3.92	1.28	0.14	0.08	24.99	0.30	+
27	*Tetracera alnifolia* Willd.	Dilleniaceae	Liane cord	Herb	60	11.67	7.00	3.23	3.45	6.18	12.87	4.21	2.63	1.52	24.99	0.20	+++
28	*Draceana arborea* (Willd) Link	Dracaenaceae	Asparagus plant	Shrub	20	2.00	0.40	1.08	0.59	0.35	2.025	0.66	-0.12	- 0.07	24.99	0.10	+
29	*Alchornea cordifolia* (Schumach & Thonn.) Mull. Arg.	Euphorbiaceae	Christmas bush	Shrub	60	3.00	1.00	3.23	0.89	0.88	5.00	1.64	0.35	0.20	24.99	0.05	+++
30	*Phyllantus* sp.	Euphorbiaceae	Stone breaker	Herb	20	2.00	0.40	1.08	0.59	0.35	2.03	0.66	-0.12	- 0.07	24.99	0.10	+
31	*Delbergia ecastaphyllum* (L.) Taub	Fabaceae	Coin vine	Herb	20	1.00	0.20	1.08	0.30	0.18	1.55	0.51	-0.15	- 0.09	24.99	0.05	+
32	*Harrungana madasgascariensis* Lam ex Poiret	Guttiferaceae	Dragon's blood	Shrub	20	4.00	0.80	1.08	1.18	0.71	4.05	1.33	0.16	0.09	24.99	0.10	+
33	*Anthocliesta liebrechstiana* De Wild & T Durand	Loganiaceae	Cabbage tree	Tree	80	1.75	1.40	4.30	0.52	1.24	6.05	1.98	0.59	0.34	24.99	0.02	++++

34	*Anthocliesta djalonensis* A. Chev	Loganiaceae	Cabbage tree	Tree	40	3.00	1.20	2.15	0.89	1.06	4.10	1.34	0.17	0.10	24.99	0.08	++
35	*Anthocliesta nobilis* G. Don	Loganiaceae	Cabbage tree	Tree	60	13.67	8.20	3.23	4.04	7.24	14.52	1.48	0.25	0.15	24.99	0.23	+++
36	*Spigelia anthelmia* Linn.	Loganiaceae	Worm plant	Herb	20	8.00	1.60	1.08	2.37	1.41	4.86	1.59	0.32	0.19	24.99	0.40	+
37	*Melastomastrum capitatum* (Vahl) A & R Fernandes	Melastomataceae	N/A	Herb	20	8.00	1.60	1.08	2.37	1.41	4.86	1.59	0.32	0.19	24.99	0.40	+
38	*Heterotis rotundifolia* (Sm.) Jacq. Fel	Melastomataceae	Cheek weed	Herb	20	30.00	6.00	1.08	8.87	5.30	15.25	4.99	3.49	2.01	24.99	1.50	+
39	*Ficus sur* Forskk	Moraceae	Fig. tree	Tree	40	1.00	0.40	2.15	0.30	0.35	2.80	0.92	-0.04	-0.02	24.99	0.03	++
40	*Ficus polita* Vahl	Moraceae	Fig. tree	Shrub	20	1.00	0.20	1.08	0.30	0.18	2.63	0.86	-0.06	-0.03	24.99	0.05	+
41	*Smithmania pubescence* Soland.	Passifloraceae	N/A	Shrub	20	2.00	0.40	1.08	0.59	0.35	2.03	0.66	-0.12	0.85	24.99	0.10	+
42	*Passiflora foetida* L.	Passifloraceae	Goat scented flower	Herb	40	3.00	1.20	2.15	0.89	1.06	4.10	1.34	0.17	0.10	24.99	0.08	++
43	*Oplismenus burmanii* (Retz) P. Beauv	Poaceae	Grass	Herb	20	25.00	5.00	1.08	7.39	4.42	12.89	4.22	2.64	1.52	24.99	1.25	+
44	*Carpolobia lutea* G. Don	Polygalaceae	Poor man's candle stick	Shrub	60	1.67	1.00	3.23	0.49	0.88	4.61	1.51	0.27	0.16	24.99	0.03	+++
45	*Acrostichum auruem* L.	Adiantaceae	Aquatic fern	Herb	20	1.00	0.20	1.08	0.30	0.18	1.55	0.51	-0.15	-0.09	24.99	0.05	+
46	*Nauclea latifolia* Sm.	Rubiaceae	West African box wood	Shrub	20	2.00	0.40	1.08	0.59	0.35	2.03	0.66	-0.12	-0.07	24.99	0.10	+
47	*Hellea leadermanii* (K. Krause)Verde	Rubiaceae	Abura	Tree	20	7.00	1.40	1.08	2.07	1.24	4.39	1.44	0.23	0.13	24.99	0.35	+
48	*Sabicea geophiliodes* Wernham.	Rubiaceae	N/A	Herb	60	10.67	6.40	3.23	3.16	5.65	12.04	3.94	2.35	0.16	24.99	0.18	+++
49	*Mussularia accuminata* (G. Don) Bullock	Rubiaceae	Mouth cleaner	Herb	20	3.00	0.60	1.08	0.89	0.53	2.50	0.82	-0.07	-0.02	24.99	0.15	+
50	*Manilkara obovata* (Sabine & G. Don) J. H. Hemsi	Sapotaceae	African pear	Shrub	40	2.00	0.80	2.15	0.59	0.71	3.45	1.13	0.06	0.03	24.99	0.05	++
51	*Lygodium smithuanum* Presl.	Schizaeaceae	Fern	Herb	40	25.50	10.00	2.15	7.54	8.83	18.53	6.07	4.75	2.74	24.99	0.64	++
52	*Lygodium microphyllum* (Cav.) R.Br	Schizaeceae	Fern	Herb	20	15.00	3.00	1.08	4.44	2.65	8.17	2.67	1.14	0.66	24.99	0.75	+
53	*Selaginella myosorus* Alston	Selaginellaceae	Fern	Herb	40	15.00	6.00	2.15	4.44	5.30	11.89	3.89	2.30	1.33	24.99	0.38	++
54	*Stachyarpheta cayennesis* (Rich)Vahl	Verbanaceae	Brazilian tea	Shrub	40	2.50	1.00	2.15	0.74	0.83	3.77	1.24	0.11	0.07	24.99	0.06	++
55	*Vitex doniana* Sweet.	Verbenaceae	Black plum	Shrub	40	2.50	1.00	2.15	0.74	0.83	3.77	1.24	0.11	0.07	24.99	0.06	++
	TOTAL				**1860**	**338.09**	**113.2**	**100.15**	**100.08**	**99.88**	**305.47**	**96.73**	**32.66**	**18.99**	**24.99**	**12.02**	

Note: %F = Percentage Frequency. D = Density (No. of individuals ha^{-1}). A=Abundance. %RF = Relative Frequency. %RD = Relative Density. %RA = Relative Abundance. IVI = Importance Value Index. DmgR = Margalef Species Richness. SdH' = Species Diversity. SdE =Species Diversity Evenness. A/F = Ratio A: F distribution pattern with the "thumb of rule" designated as follows: Regular (< 0.03), Random (0.03-0.05) and Contiguous (> 0.05) distribution. + (1-25) Very Scarce,+ (26-29) Scarce, +++ (60-79) Abundant, ++++> (80-α) Very Abundant, NA – Not Available.

Table 7: Soil Physico-Chemical Properties of the sampled sites in Asarama Study Sites

Soil Levels	Sampled Site	Physico-Chemical Properties					
		pH	MC (Wt %)	EC (µS/cm)	Salinity (ppt)	OC (Wt %)	OM (Wt %)
Surface	Mangrove (MS)	4.24[b]	47.31[a]	3753[a]	0.91[b]	2.05[ab]	3.56[ab]
	Ecotone (ES)	4.64[ab]	47.12[a]	1165[bc]	0.59[bc]	2.07[ab]	3.58[ab]
	Rainforest (RS)	4.72[ab]	41.29[a]	331[c]	0.17[c]	2.38[a]	4.12[ab]
Subsurface	Mangrove (MSS)	3.40[c]	47.33[a]	3085[ab]	1.57[a]	1.51[b]	2.61[b]
	Ecotone (ESS)	4.82[a]	47.12[a]	953[bc]	0.48[bc]	2.08[ab]	3.60[ab]
	Rainforest (RSS)	5.24[a]	41.30[a]	312[c]	0.16[c]	2.17[ab]	4.94[a]
Mean		**4.51**	**45.24**	**1599.82**	**0.65**	**2.04**	**3.73**
LSD (P<0.05) (df=24)		**0.83**	**9.34**	**2133**	**0.57**	**0.75**	**1.60**

Note: MS = Mangrove Surface, **MSS** = Mangrove Subsurface, **ES** = Ecotone Surface, **ESS =** Ecotone Subsurface, **RS** = Rainforest Surface, **RSS** = Rainforest Subsurface; **MC** = Moisture Content; **EC** = Electrical Conductivity; **OC** = Organic carbon; **OM** = Organic matter.

Table 8: Pearson Correlation of Physico-Chemical Properties of the sampled sites in Asarama Study Sites

	pH	MC (Wt %)	EC (µS/cm)	Salinity (ppt)	OC (Wt %)	OM (Wt %)
pH	1.00					
MC (Wt %)	-0.49	1.00				
EC (µS/cm)	0.08	-0.41	1.00			
Salinity (ppt)	0.27	-0.43	0.59	1.00		
OC (Wt %)	-0.55	0.54	-0.27	-0.35	1.00	
OM (Wt %)	-0.09	0.16	-0.27	-0.15	0.18	1.00