Functional Trait and Phylogenetic Diversity of Tree and Shrub Species in three Tropical Forests across Anambra State Nigeria

ABSTRACT

Understanding which species coexist, their roles, and interactions enrich our knowledge of local ecosystems; and, the ecosystem services rendered by forests are paramount. Identifying key tree species allows us to assess their contributions to ecosystem services such as carbon sequestration, soil stability, and habitat provision. This research examined the functional trait and phylogenetic diversity of tree and shrub species in three tropical forests in Anambra State. A combination of line transects and plot sampling was used in this study. Field inventory of tree flora was undertaken to collect data. At each location, six plots of 10 m × 10 m each were randomly demarcated using a line cut and the trees within the plots were assessed. The identification and recording of different tree species was carried out according to the Linnaeus taxonomy of species classification. Functional leaf characteristics (dry mass, size and specific area) were recorded for at least two healthy, unshaded adults of the different species. Phylogenetic diversity was determined by constructing phylogenetic trees. All data analysis for this study was performed using the Python programming language. The Statistical Package for Product and Services was used to provide supplementary analyzes such as dendrogram plotting. The metrics of functional diversity, including Rao's squared entropy (Rao's Q), functional richness, functional evenness and functional divergence, for the three plant communities were also presented. Phylogenetic representation of all tree and shrub species included in the analysis of NACF, IFU and UFA, based on species abundance data, revealed several distinct clusters within the dendrogram and some close clusters, indicating close relationships between species in the dendrogram dense cluster. There were also intermediate and distant clusters that showed moderate similarities and differences in relationships, respectively. Overall, the diversity of functional traits examined in this study provides valuable insights into ecosystem functioning. This will be helpful to researchers, and other stakeholders can use this information to model carbon sequestration, nutrient cycling, and other ecosystem services.

KEYWORDS: Functional, Phylogentic, Forest, Tree, Shrub, Plant, Species, Ecology, Conservation

1.0 INTRODUCTION

Phylogenetic systems classify plants mostly according to their supposed evolutionary relationship or heredity. Notably, even to date, these systems are to a large extent based on the former artificial systems of Linnaeus [1]. Barnosky*et al* [2] have argued vehemently that we are living through a huge extinction event that is more than the five previous mass extinctions in the history of the Earth's. The recent trend in biodiversity loss is majorly happening due to a combination of events such as habitat loss, habitat modification, and climate change [2], [3]. A good number of studies have raised concerns that habitat loss leads to a diversity decrease in many taxa, including plants and other living organisms [4], [5]. The consequences go further than just the loss of species; they also involve a decline in evolutionary history and ecological processes, thereby affecting the ability of forests to attain self sustainability in the long run [6]. However, a good number of these studies were based on species richness (SR), and there is a rational agreement that species richness actually results in limited information on evolutionary history and function [7]. The incorporation of phylogenetic and functional diversity affords additional awareness about ecological processes and may also provide reliable information about ecosystem function [8]. Contemporarily, it is becoming a norm to include phylogenetic and functional diversity to represent vital biodiversity aspects that are also obviously necessary for the comprehension of plant community assembly in human modified landscapes.

When it comes to plant phylogenetic diversity (PD), the outcomes are differing. Andrade *et al.* [9] in their study, recorded unwanted effects of anthropogenic activities that affect phylogenetic relationships; either by restricting diversity or disrupting the structure by increasing phylogenetic clusters. Although most studies observed an increase in PD or a phylogenetic overdispersed structure in disturbed areas, mainly due to the addition of non-native species [10]; yet, there is a surging number of studies reporting that PD can be sustained in several tropical landscapes including highly disturbed forests [11]. Studies have reported that for functional diversity (FD), anthropogenic activities may cause either no effects [12], negative effects [13], [14] or positive effects [15] on plant community functional responses.More so, there is a distinct bias towards studies concentrating on adult tree assemblages. In this regard, adult trees most times, portray the accumulated responses to historical variations because they are likely to persist in the landscape for a longer time [5]. In contrast, recently established individuals, such as seedlings and juveniles, show a heightened responsiveness to habitat loss due to recent disorderly effects in reproductive, dispersal, and establishment processes controlled by deforestation [5]. In order word, there is an expectation that clear reactions to anthropogenic disturbances are among life-stage groups, which can result to divergent responses to richness, evolutionary history and ecological functions [16]. Anthropogenic activities can disrupt local microclimatic conditions such as solar radiation available in the forest understory [17], which impact the development and thriving of juvenile plants [18]. The younger assemblages hold the future of the forest, and afford more reliable information on the repercussions of forest loss in the long term [6]. Moreover, in as much as this knowledge is relevant for conservation decisions, these studies are still scanty.

Phylogenetic diversity (PD) and functional diversity (FD) are very efficient quantitative measures of biodiversity that may aid to make clear how biodiversity is interconnected to ecosystem processes [19], [20]. The evolutionary history of species that occur together and can serve as a substitute for gauging the diversity of species' ecological roles in a community are all accounted for by phylogenetic diversity. Distantly related species carry out more unique functional roles than species that are closely related, more so, there is an increased metric for species that occur together to have distant, instead of recent common ancestors [19]. Functional diversity (FD) is made of the range of functional traits present in the organisms occurring together and measures the discreteness of a community in terms of functional traits [12]. For instance, it represents the diversity of Eltonian species' niches or roles in a community [21] determined by species morphology [22]. Another component of functional diversity is functional identity, which shows the functional make up of a specific trait in a community and impacts trophic interactivities among species and ecosystem processes [23], [24]. PD and FD make available more information than just species richness or abundance [19], [25] because they portray ecological divergence among species that is likely associated with species' contributions to ecosystem functioning [26]. Although functional diversity measures of FD account for the functional traits that are useful for a specific ecological function, for instance, a set of morphological traits exhibited by frugivores [22], Phylogenetic diversity in addition takes care of unmeasured traits, such as behavioral, life history or physiological traits, these traits are usually connected with the phylogenetic history of species [27]. Hence, studying both PD and FD is necessary for an in-depth understanding of how complementary plant-animal interactions shape ecological communities and their associated ecosystem functions.

The latest trend in global climate change research is the application of phylogenetics to give a clear comprehension and forecast the influence of global change [28], [29], [30], [31], [32]. Taxa that are closely related have the capability to react in a similar way to global environmental changes, and this is as a result of shared evolutionary histories, genetic background, and phenotypic traits within the taxa. More so, taking phylogeny into consideration may afford a general view that is more suitable for modelling the impacts of large-scale global climate change rather than making it general across species that share basic niches. For instance, Davis *et al.* [31] evaluated the flowering time of plant clades occurring in both the United States and the United Kingdom and discovered that phenological responses to global climate change were distributed within clades. Related trends are liable to occur as a response of other plant traits to other large-scale disturbances. An example is the magnitude of CO_2-induced rise in biomass may differ much more within functional types (e.g. herbaceous vs woody species) than among functional types [33], although there may be rise in response with consistent variations when functional groups align with major phylogenetic differences such as gymnosperms vs. angiosperms [34]. Consequently, only a few studies make use of a clear phylogenetic framework to evaluate the importance of phylogeny [28], [30], [31], [32]. Such an approach is relevant since the distinctness found amongst plant functional groups that are currently being investigated in global change studies, most likely indicate the evolutionary consequences of phylogenetic divergence [35], [36], [37]. Evaluating phylogenetic responses to climate change may expose a broader range of variation, Cadotte*et al.* (2012) among taxa for adequate understanding of how plants can react to increasing CO_2, N or other environmental factors.The aim of this study was to ascertain the functional traits between tree and shrub families, and between forest sites in Anambra State, as well as determine the phylogenetic diversity of the three forest sites.

2.0 MATERIALS AND METHOD

2.1 Study Area

The study was carried out in Anambra state, Nigeria. It lies within the tropical rain and evergreen forest with a tropical climate that is humid all year round; although the humidity varies with the seasons. The rainy season spans from March to October and is bimodal with a two-week break of rainfall in August (August break). The mean annual rainfall in the southeast is 2000m while the average annual temperature is between 25^0C and 28^0C with relative humidity of about 98% during the rainy season and between 50% and 60% during dry season (ADP, 2010).

Three tropical forests were selected from different zones of the study area based on their high floristic composition:

1. Unizik Conservation Forest Nnamdi Azikiwe University, Awka (6^O15’14”N 7^O06’37”E).
2. IshigwuForest, UmuomakuOrumbaSouth LGA (5^O57’36”N 7^O08’52”E).
3. Umuikwu Forest, Anam Anambra West LGA (6^O14’12”N 6^O45’50”E).

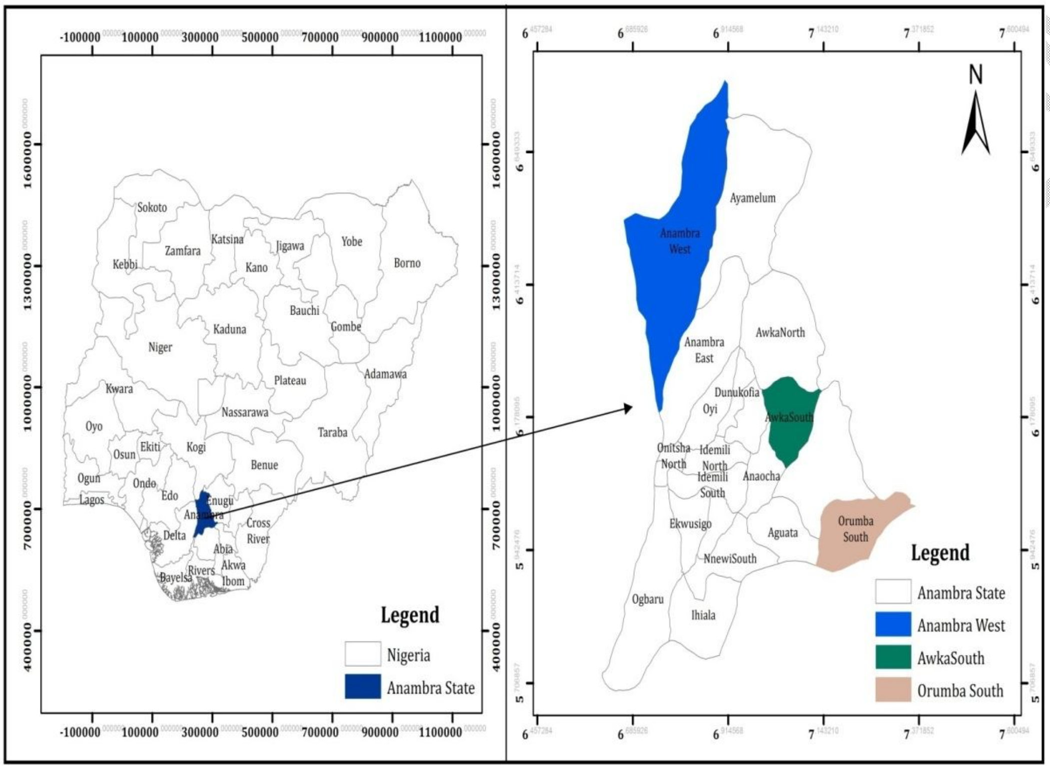

Figure 1: Map of Nigeria Showing Anambra State and the Three Local Government Areas Where the Forest Sites Studied are Located

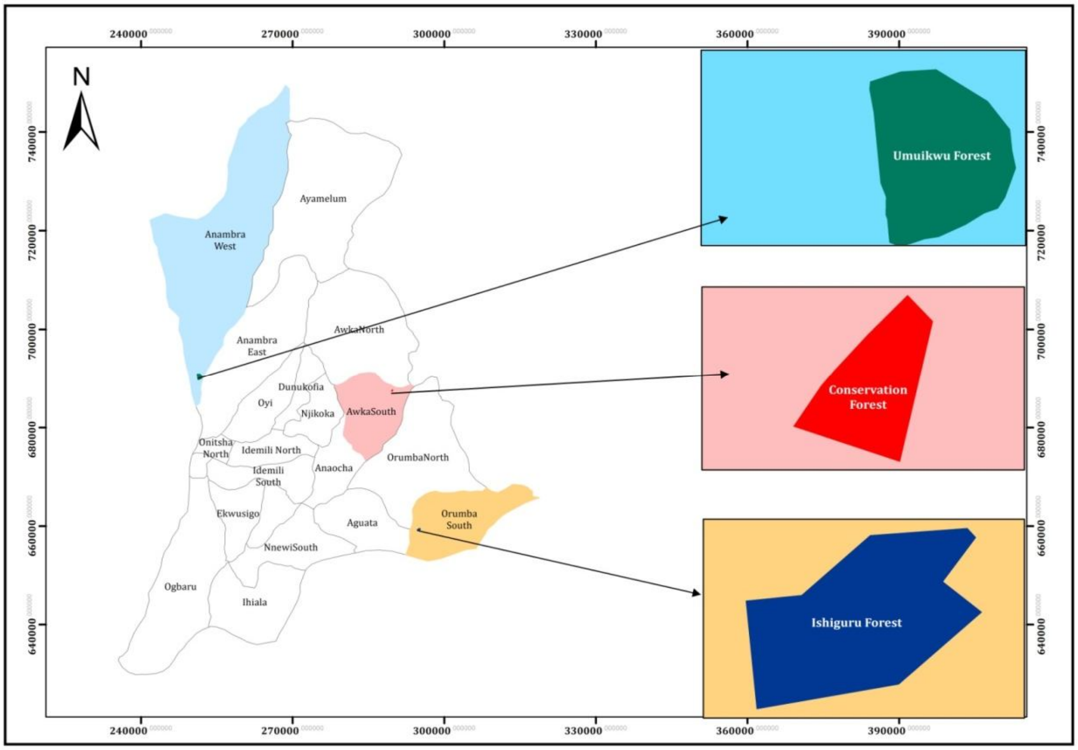

Figure 2: Map of Anambra State Showing the Particular Location in the Local Government Areas Where the Forest the Forests are Located

Figure 3: Aerial Map Showing the Nnamdi Azikiwe Conservation Forest Awka South LGA

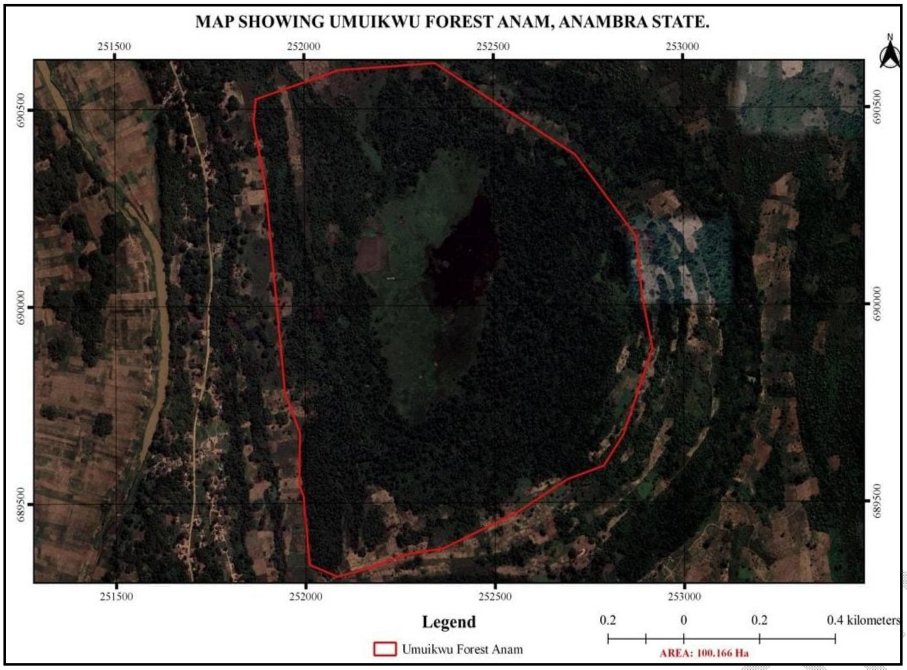

Figure 4: Aerial Map Showing the Umuikwu Forest Anam Anambra West LGA

Figure 5: Aerial Map Showing the Ishigwu Forest UmuomakuOrumba South LGA

2.2 Study Design

A combination of line transects and plot sampling was used in this study. To ensure proper spread and representation, multi stage random sampling technique was used. Stage one was the selection of forest sites from each of the zones in the state (Anambra south, Anambra central and Anambra north), selection was based on the 4 cardinal points of east, west, north and south of the state; also, anthropogenic activities was put into consideration in the selection. Stage two involved the random selection of plots inside the forests selected for the study. A field inventory of treesand shrubs flora was adopted for data collection. On each location, six plots of 10 m × 10 m each were randomly demarcated following a line transect and trees within the plots were assessed.

2.3 Functional Diversity

Leaf functional traits (dry mass, size andspecific area) were recorded for at least two healthy, unshaded adults from the different species [39]. For leaf traits, five intact, fully exposed leaves (except under-storey species) were collected per plant species. Species for which fewer than two individuals were accessible to collect samples were not included in the analysis.

2.3.1 Leaf Area (Size): Leaves of the plants were measured using a ruler; the leaf length and width were multiplied to get the area of the leaf.

Leaf area (cm^2) = L x W x 0.75

Where:
L= Leaf length

W = Leaf width

0.75 = Contant

For compound (Pinnate) and double compound (Bipinnate) leave area; first, the length of leaflets were measured, then the mean (average) length of all the leaflets measured was calculated. Next, the widths of the widest leaflet (usually the terminal leaflet) were measured, and the mean was determined.To calculate the total leaflet area; the mean length was multiplied by the mean width to obtain the average leaflet area.This average leaflet area represents the typical size of an individual leaflet in the compound leaf. And then the total compound/double compound leaf area was calculated by multiplying the average leaflet area by the total number of leaflets in the compound leaf. The result gave the estimated area of the entire pinnate/bipinnate leaf.

2.3.2 Leaf Dry Mass: At least five leaveswas collected randomly from each tree encountered in the forestand were dried in the oven (E8A76739-Genlab) at a temperature of 60-65°C until theyreached a constant weight; thiswas done to remove all the moisture from the leaf to get the dry mass. The dried leaves were then weighed with a Sartorius MCE623P-2S00-I Cubis II Precision Weighing Balance and figures were reported in grams.

2.3.3 Specific Leaf Area: To calculate the specific leaf area of the leave samples, the leaf area and dry mass of the leaf were first measured. The specific leaf area was then calculated as the ratio of leaf area to leaf dry mass. The area of the leave was divided by the dry mass of the leaf to get the specific leaf area.

Specific leaf area (cm^2/g) = $\frac{\text{Leaf area}}{\text{Leaf dry mass}}$

2.4 Phylogenetic Diversity

A complete list of species with the families following APG III [40] was collected. Morphotyped species were excluded from the list because their phylogenetic position could not be accurately resolved. Phylogenetic diversity was determined by constructing a phylogenetic tree [41], based on species abundance data. The phylogenetic tree was then used to measure the evolutionary cluster and distance among the species.

2.4 Data Analysis

All data analysis for this study was conducted using Python programming language, leveraging libraries such as pandas for data manipulation, NumPy for numerical computation, and scikit-learn for statistical modeling. The analysis was performed within the Jupyter Notebook environment, allowing for transparent and reproducible data analytics. Statistical Package for Social Sciences was use to provide complementary analysis such as the plotting of dendrogram.

3.0 RESULT

3.1 Functional diversity measured as Rao's Quadratic Entropy (Rao's Q), functional richness, functional evenness, and functional divergence of trees and shrubs

The results presented in Table 1 showed the functional diversity metrics, including Rao's quadratic entropy (Rao's Q), functional richness, functional evenness, and functional divergence, for three distinct plant communities; Nnamdi Azikiwe Conservation Forest (NACF), Ishigwu Forest Umuomaku (IFU), and Umuikwu Forest Anam (UFA).

The table illustrated that the NACF site exhibited notably higher values across all metrics compared to the IFU and UFA communities. Specifically, Rao's Q, indicative of overall functional diversity, was highest in the NACF site with a value of 0.728, closely followed by IFU at 0.725, and then UFA at 0.712. This signified that the NACF site had the highest overall functional diversity among the studied sites.

Functional richness was highest in the NACF site at 0.678, followed by IFU at 0.641, and then UFA at 0.521. This implied that the NACF site encompassed a broader spectrum of functional trait combinations compared to its counterparts.

In terms of functional evenness, denoting the uniformity of species distribution across various trait values, the NACF site exhibited the lowest value at 0.348. Conversely, UFA site displayed the highest evenness at 0.683.

Functional divergence, indicating the extent of deviation of the most abundant species from the centroid of the trait space, was most pronounced in the NACF site at 0.811, followed by UFA at 0.691, and IFU at 0.654. This highlighted that the NACF site exhibited greater variability or dispersion of species in their functional traits compared to the other sites.

Table 1: Functional Diversity Measured as Rao's Quadratic Entropy (Rao's Q), Functional Richness, Functional Evenness, and Functional Divergence

Metric	NACF	IFU	UFA
Rao's Q	0.728	0.725	0.712
Functional richness	0.678	0.641	0.521
Functional evenness	0.348	0.505	0.683
Functional divergence	0.811	0.654	0.691

3.2 Phylogenetic Diversity of the Three Forest Sites

3.2.1 Dendrogram showing the Phylogenetic Diversity in NACF Study Site

Figure 6a and 6b shows the phylogenetic representation of all the species included in the analysis fromNnamdi Azikiwe Conservation Forest (NACF) based on species abundance data. Several distinct clusters were observed within the dendrogram.

- **Close Clusters:** Species like *Sterculia tragacantha* and *Cola hispida* merged at a low height, indicating a high degree of similarity. Similarly, *Pycnanthusangolensis* and *Brachystegiaeurycoma* merged at a low height, suggesting they were closely related.
- **Intermediate Clusters:**The cluster comprised of species like *Elaeisguineensis*, *Afzeliabipindensis*, and *Ficussycomorus*. They merged at an intermediate height, reflecting moderate similarity among these species.
- **Distant Clusters:**Species such as *Musangacecropioides* and *Miliciaexcelsa* merged at a higher height, indicating significant differences from other species within their cluster.

Further analysis at a height of approximately 10 units of rescaled distance revealed several distinct groups.

Group 1: Included species like *Sterculia tragacantha*, *Cola hispida*, *Rothmanniawhitfieldii*, *Entada abyssinica*, and *Uvariachamae.*

Group 2: Comprised species such as *Pycnanthusangolensis*, *Brideliamicrantha*, *Gmelina arborea*, and *Heisteriaparvifolia*.

Group 3: A larger cluster ranging from *Elaeisguineensis* to *Citrus aurantium*.

Group 4: An extensive group from *Musangacecropioides* to *Anthocleistadjalonensis.*

Group 5: Included species such as *Tremaorientalis*, *Ceiba pentandra*, *Nauclealatifolia*, and *Daniella oliveri*.

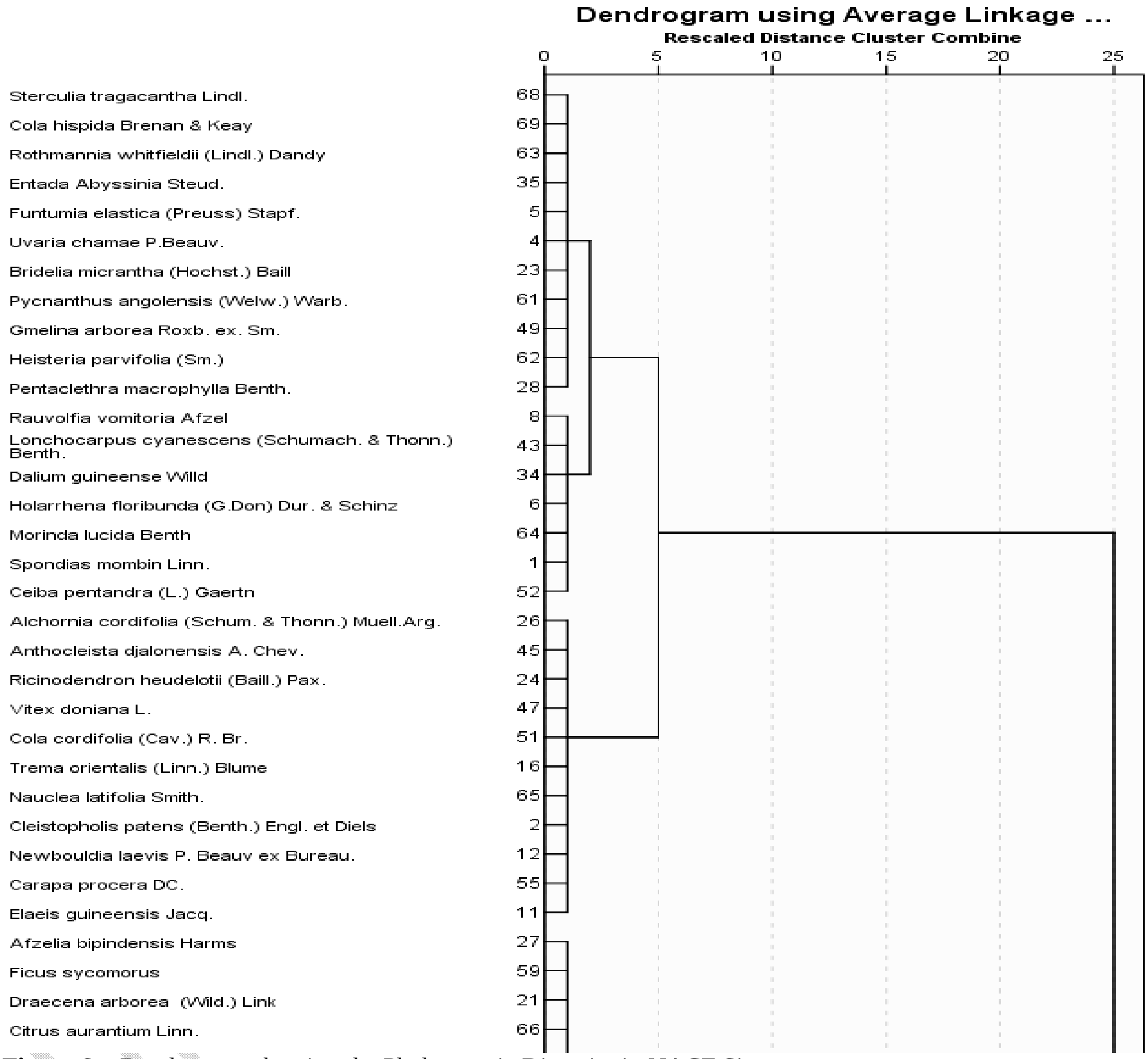

Figure 6a: Dendrogram showing the Phylogenetic Diversity in NACF Site

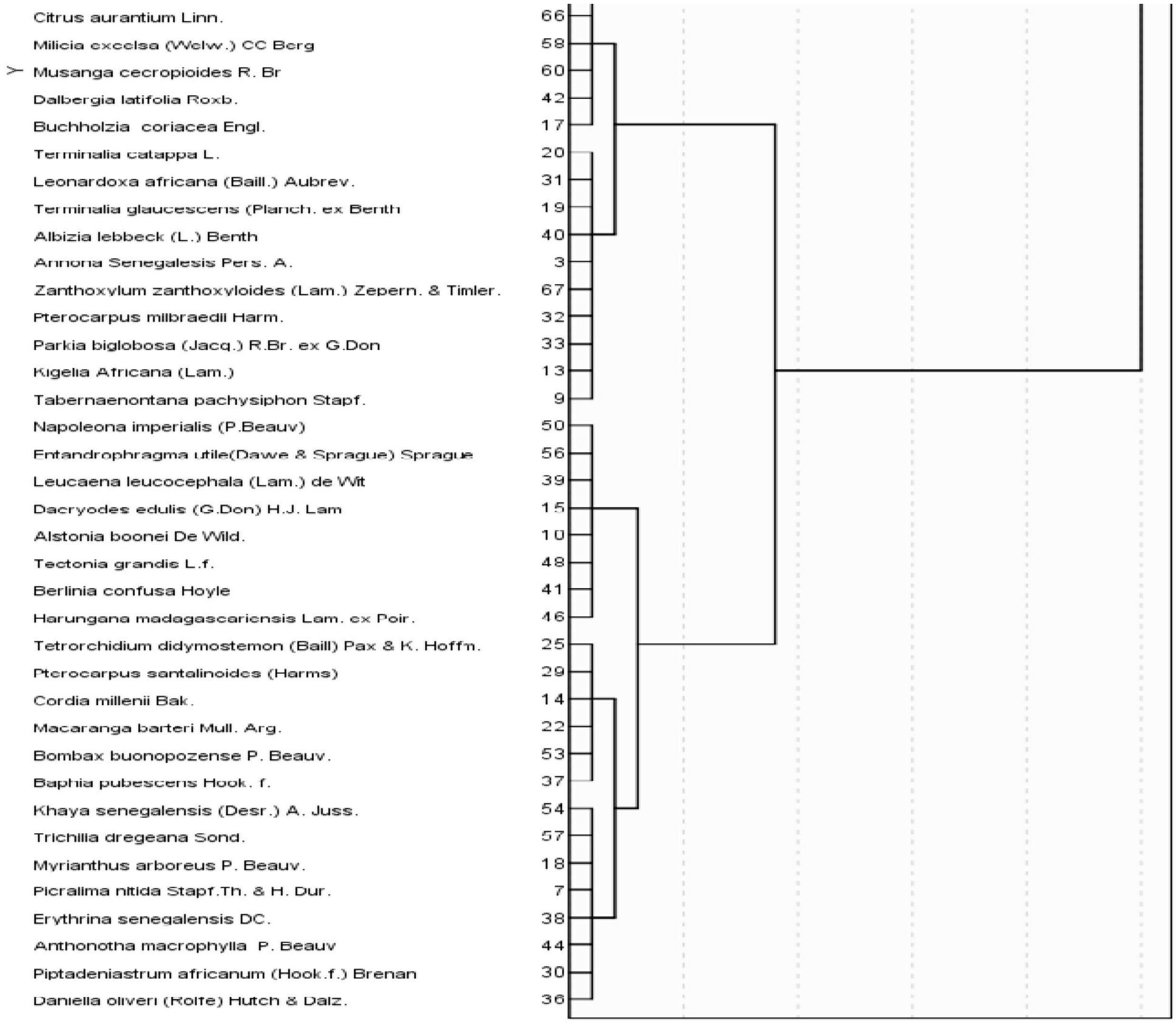

Figure 6b: Dendrogram showing the Phylogenetic Diversity in NACF Site

3.2.2 Dendrogram showing the Phylogenetic Diversity in IFU Study Site

Figure 7a and 7b shows the phylogenetic representation of all the tree and shrub species included in the analysis from Ishigwu Forest Umuomaku (IFU) based on species abundance data. Several distinct clusters were observed within the dendrogram.

- **Close Clusters:** Species such as *Miliciaexcelsa* and *Glyphaebrevis* merged at a low height, indicating a high degree of similarity. Similarly, *Garciniakola* and *Xylopia aethiopica* merged at a low height, suggesting their close relationship.
- **Intermediate Clusters:** This cluster included species such as *Nauclealatifolium*, *Hildegardiabarteri*, and *Brachystegiaeurycoma*, which merged at an intermediate height, reflecting moderate similarity among them.
- **Distant Clusters:** Species like *Elaeisguineensis* and *Diospyrossuavelons* merged at a higher height, indicating significant differences from other species within their cluster.

Further analysis at a height of approximately 10 units of rescaled distance revealed several distinct groups.

- **Group 1:** Included *Miliciaexcelsa*, *Glyphaebrevis*, *Canariumschweinfurthii*, *Icacinatrichantha*, and *Pycnanthusangolensis*.
- **Group 2:** Comprised *Nauclealatifolium*, *Hildegardiabarteri*, and *Brachystegiaeurycoma.*
- **Group 3:** A larger cluster ranging from *Garciniakola* to *Hannoaklaineana.*
- **Group 4:** An extensive group from *Sterculiatragacantha* to *Elaeisguineensis.*

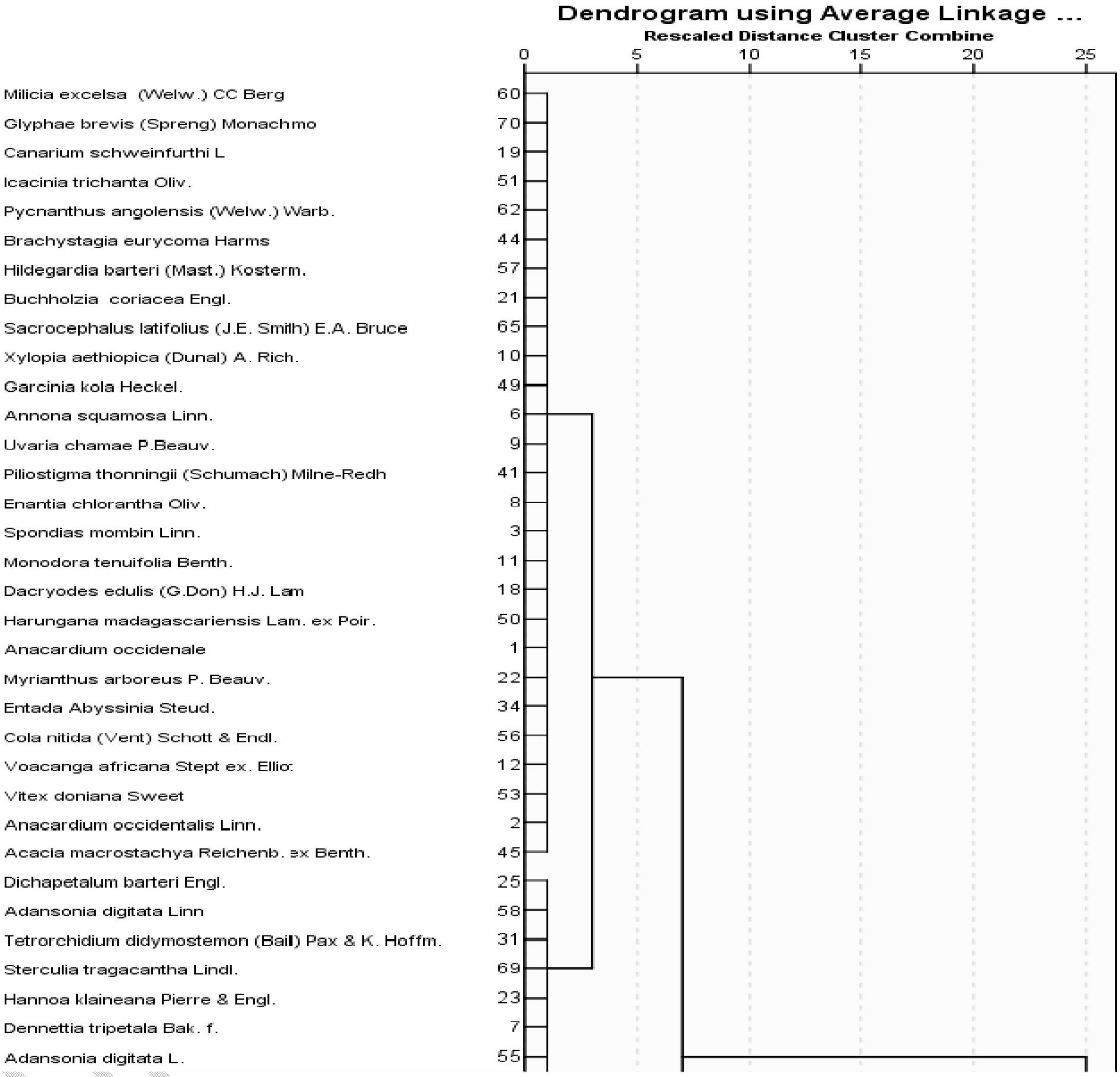

Figure 7a: Dendrogram showing the Phylogenetic Diversity in IFU Site

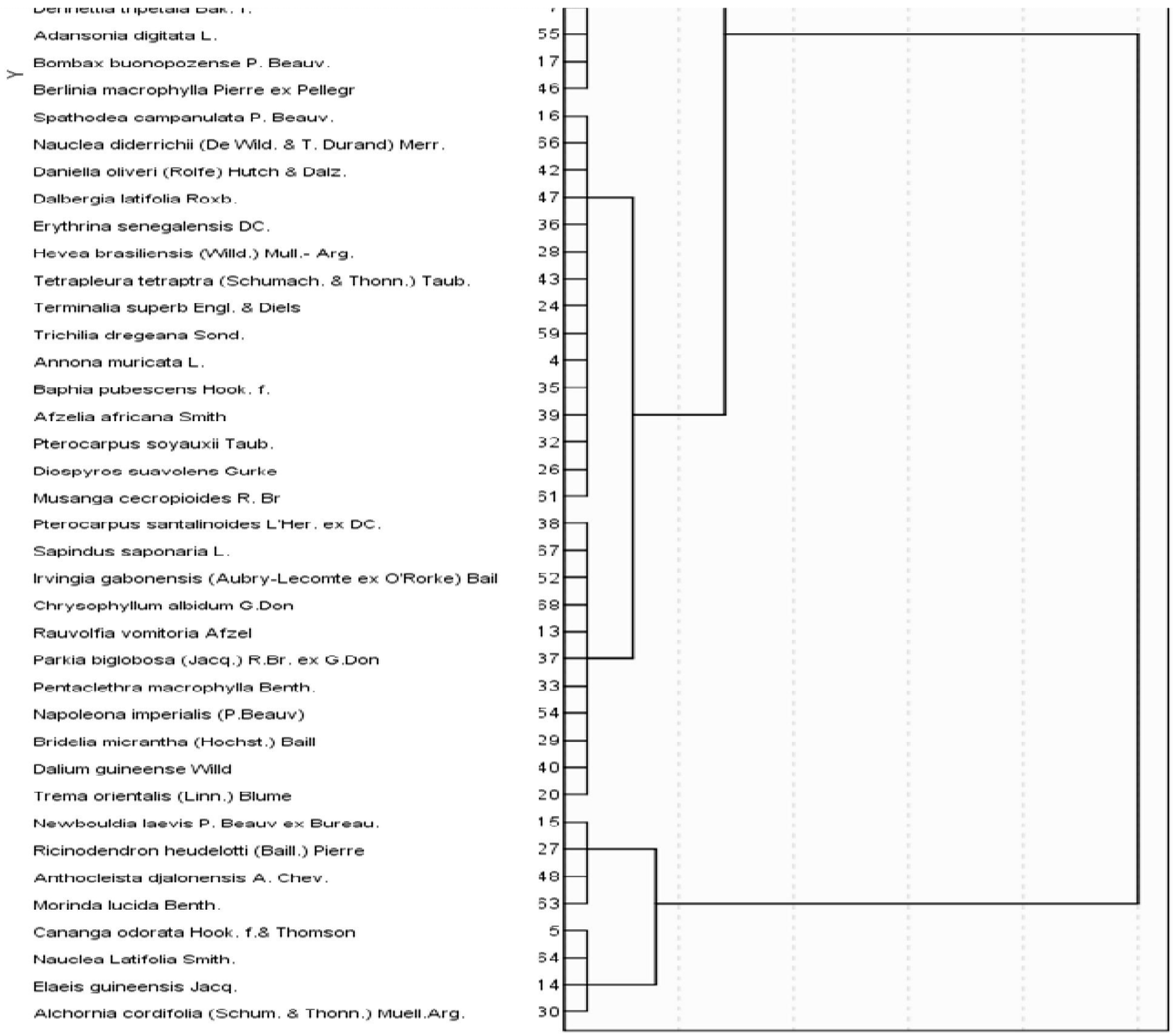

Figure 7b: Dendrogram showing the Phylogenetic Diversity in IFU Site

3.2.3 Dendrogram showing the Phylogenetic Diversity in UFA Study Site

Figure 8 shows the phylogenies representation of all the species included in the analysis fromUmuikwu Forest Anam (UFA) based on species abundance data. Several distinct clusters within the dendrogram were observed.

- **Close Clusters**:For instance, *Sterculia tragacantha* and *Glyphae brevis* merged at a low height, indicating a high degree of similarity.Similarly, *Garcinia kola* and *Daniellaoliveri* merged at a low height, suggesting they were closely related.
- **Intermediate Clusters:**Example of this cluster comprises of*Hildegardiabarteri*, *Chrysophyllumalbidum*, and *Pterocarpussoyauxii* merging at an intermediate height, reflecting moderate similarity among these species.
- **Distant Clusters:**Species such as *Elaeisguineensis* and *Diospyroszenkeri* merged at a higher height, indicating significant differences from other species within their cluster.

Further results at a height of approximately 10 units of rescaled distance revealed several distinct groups.

- **Group 1:** Included species like *Sterculia tragacantha*, *Glyphyae brevis*, *Hannoaklaineana*, and *Tabernaemontanapachysiphon*.
- **Group 2:** Comprised species like *Garcinia kola* and *Danielliaoliveri*.
- **Group 3:** A larger cluster ranging from *Hildegardiabarteri* to *Monodoratenuifolia*.

- **Group 4:** An extensive group from *Naucleadiderrichii* to *Elaeisguineensis.*

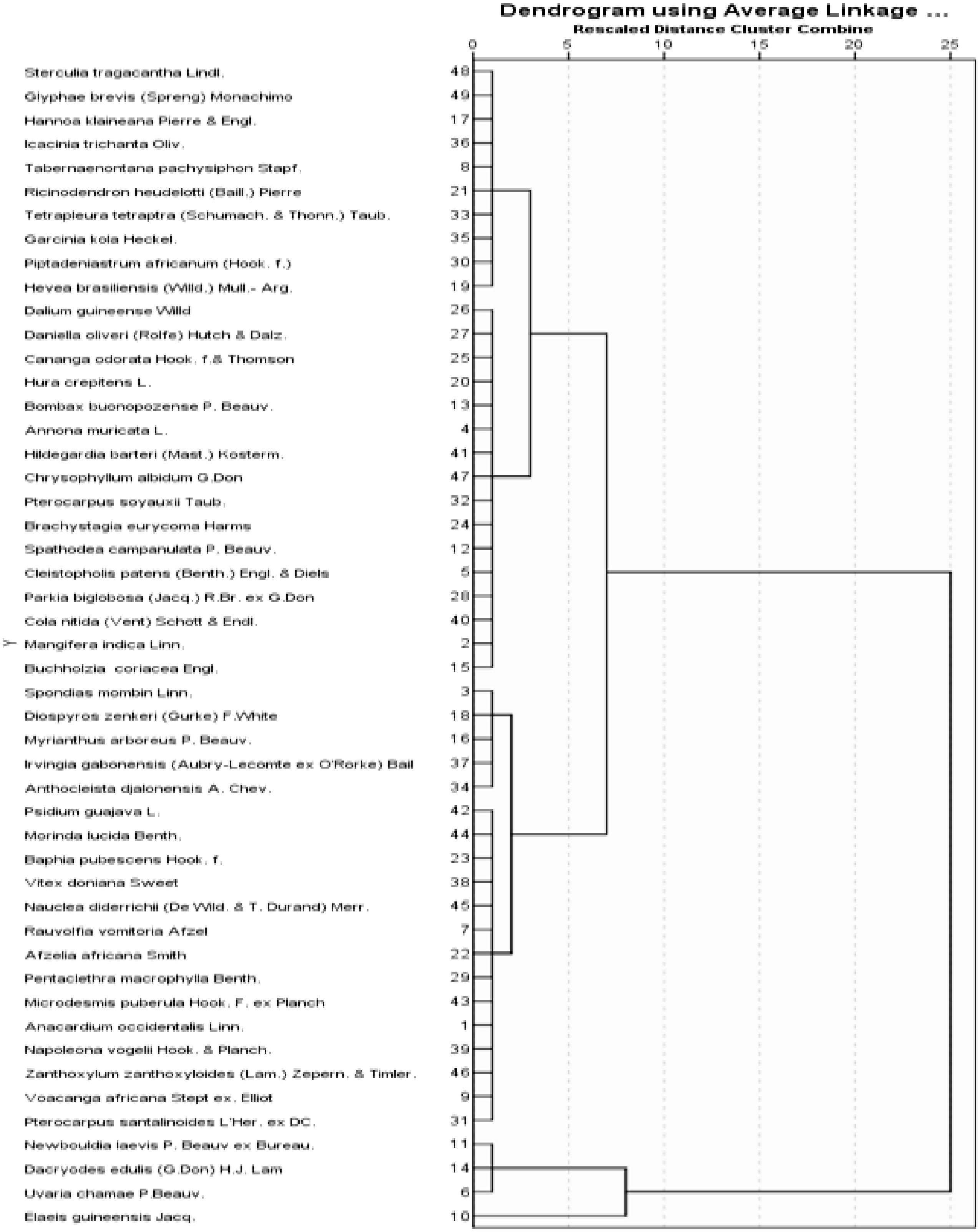

Figure 8: Dendrogram showing the Phylogenetic Diversity in UFA Site

4.0 DISCUSSION

4.1 Functional Diversity

The results presented in Table 1 showed the metrics of functional traits diversity, including Rao's squared entropy (Rao's Q), functional richness, functional evenness, and functional divergence for the three forest areas; Nnamdi Azikiwe Conservation Forest (NACF), Ishigwu Forest Umuomaku (IFU) and Umuikwu Forest Anam (UFA). The table shows that the NACF site had significantly higher scores on all metrics compared to the IFU and UFA study sites. Specifically, Rao's Q, an indicator of overall functional diversity, was highest at the NACF site with a value of 0.728, closely followed by IFU at 0.725 and UFA at 0.712. This meant that the NACF site had the highest overall functional diversity among the sites studied. Functional diversity has been proposed as an important feature of biological assemblages, allowing prediction of the rate and reliability of ecosystem processes (i.e., ecosystem function and ecosystem reliability) [42]. “Functional diversity” has been used to describe different aspects of community or ecosystem structure, such as: the variation in functional traits of plant species [43], [44], [45]; the complexity of food webs [46] and the number of plant functional groups present [25]. In simple terms, plant functional diversity is traits that include morphological, physiological and chemical properties that influence how plants interact with their environment and other organisms.

Functional richness was highest at the NACF site at 0.678, followed by IFU at 0.641 and UFA at 0.521. This implied that the NACF site encompassed a broader range of functional feature combinations compared to its counterparts. Low functional richness indicates that some of the resources potentially available to the community are unused. This will reduce productivity [47]. If functional character represents environmental tolerances, lower functional richness means that under certain environmental conditions there is a lack of species that could exploit the conditions, resulting in less buffering against environmental fluctuations [48]. Invasion resistance may also be lower because there are gaps in niche space that an invader can exploit [49]. Measuring functional richness depends on knowledge of the distribution of abundance of each species in the forest. To describe the distribution, measurements are required for each trait from multiple individuals of each species. In this study, leaf area, leaf dry mass, and specific leaf area were the functional traits used to measure the functional diversity of trees and shrubs in the forest sites. Mason *et al.* [42]reported examples of communities where functional richness was higher (FRci-0.857) and lower (FRci-0.500), and these are consistent with the figures in this present study. Thus, functional richness can either remain unchanged or increase with increasing species richness [44].

In terms of functional evenness, which refers to the evenness of species distribution across different trait values, the NACF site had the lowest value at 0.348. Functional evenness may be seen as the degree to which the biomass of a community is distributed in forest space to allow effective utilisation of the entire range of resources available to it (i.e. within the forest space it encompasses). Assuming resource availability is even throughout forest space, lower functional evenness indicates that some parts of forest, whilst occupied, are underutilised. This will tend to decrease productivity and reliability, and increase opportunity for invaders.

Conversely, the UFA site had the highest evenness at 0.683 while NACF had the lowest functional evenness at 0.348. Functional divergence, which indicates the extent to which the most abundant species diverge from the centroid of trait space, was most pronounced at the NACF site at 0.811, followed by UFA at 0.691 and IFU at 0.654. This highlighted that the NACF site had greater variability or spread of species in their functional traits compared to the other sites. High functional divergence indicates a high degree of ` forest differentiation, and thus low resource competition. Thus communities with high functional divergence may have increased ecosystem function as a result of more efficient resource use.

Similar to taxonomic diversity, all metrics for functional diversity were higher compared to other studies [50]. Functional richness, evenness and divergence are complementary measures that give us an idea of the size and configuration of the functional space of a plant community [21]. The results of this study suggest that the occupied functional space is larger (i.e., greater functional richness), more evenly distributed (i.e., greater functional evenness), and the distance between the most abundant taxa and the centroid of the functional space is larger (i.e., greater functional divergence) in the three forests. Also, Rao’s quadratic entropy is an independent measure of functional diversity, suggesting that functional diversity is also significantly high in the forests studied.

4.2 Phylogenetic Diversity

Figures 6a, 6b, 7a, 7b and 8 show the phylogenetic representation of all tree and shrub species included in the analysis from the Nnamdi Azikiwe Conservation Forest (NACF), the Ishigwu Forest Umuomaku (IFU) and the Umuikwu Forest Anam (UFA) based on species abundance data. Several different clusters were observed in the dendrogram. Studies have shown that dendrograms, or phylogenetic trees, provide insights into the hierarchical relationships between different plant species because of their similarity. In general, the diameter class structure of all individuals in the plots shows an obvious "L" shape based on the phylogenetic structure generated from the three forest sites. This shape indicates that the community is well regenerated and belongs to a growing population; In other words, the forests are actively growing and maintain a variety of tree and shrub species. Furthermore, the phylogenetic diversity showed in figures 6, 7, and 8 shows that the distribution of trees and shrubs is influenced by scale, size and heterogeneity of the habitat. This simply means that as the diameter class increases, the degree of aggregation (clustering) decreases and therefore most tree and shrub families tend to be more evenly distributed, while other trees may cluster together, as seen at the NACF, IFU and especially UFA study site.

Figure 6a and 6b presents the phylogenetic representation of every species analyzed from the Nnamdi Azikiwe Conservation Forest (NACF). The dendrogram revealed multiple distinct clusters. Close clusters which depicts a high degree of similarity was indicated by the merging of species at a low height, such as *Cola hispida*and *Sterculia tragacantha. Pycnanthusangolensis* and *Brachystegiaeurycoma* also merged at a low height, indicating a close relationship between them. *Elaeisguineensis, Afzeliabipindensis,* and *Ficussycomorus* are among the species that make up the intermediate clusters. There was a moderate degree of similarity between these species as they merged at an intermediate height. Species that merged at a higher height in distant clusters, like *Miliciaexcelsa* and *Musangacecropioides,* indicated notable distinctions from other species in their cluster. Subsequent examination at a height of roughly 10 rescaled distance units identified multiple discrete groups; first group contains species such as *Uvariachamae, Rothmanniawhitfieldii, Cola hispida, Entada abyssinica,* and *Sterculia tragacantha*. The second group contains species like *Heisteriaparvifolia, Brideliamicrantha, Gmelina arborea,* and *Pycnanthusangolensis*. More so, group 3 had more extensive cluster that includes *Citrus aurantium* and *Elaeisguineensis.* And lastly for NACF, broad group that includes *Anthocleistadjalonensis* and *Musangacecropioides*were on the fourth cluster in the same height, while species in the fifth cluster include:*Tremaorientalis, Ceiba pentandra, Nauclealatifolia,* and *Daniella oliveri.*

Figure 7a and 7b presents the phylogenetic representation of all the tree and shrub species analyzed from Ishigwu Forest Umuomaku (IFU). Within the dendrogram, multiple unique clusters could be seen. For the close clusters, high degree of similarity species like *Glyphae brevis* and *Miliciaexcelsa* merged at low height. Likewise, the low height of the merger between *Xylopia aethiopica* and *Garcinia kola* suggests their close relationship. Clusters at an Intermediate height had species in this cluster which included; *Nauclealatifolium, Hildegardiabarteri,* and *Brachystegiaeurycoma,* merged at a moderate height, suggesting moderate similarity among them. Clusters at a greater height had species such as *Elaeisguineensis*and *Diospyros suavelons* merged at a higher height, indicating significant differences from other species within their cluster. Numerous distinct groups were identified by additional analysis conducted at a height of roughly 10 units of rescaled distance. *Glyphae brevis, Canariumschweinfurthii, Icacinatrichantha, Pycnanthusangolensis,* and *Miliciaexcelsa* were included in group 1 while group 2 consists of *Hildegardiabarteri, Brachystegiaeurycoma,* and *Nauclealatifolium.* Group 3 and 4 had broader grouping that includes *Hannoaklaineana*and *Garcinia kola*; and species group ranging from *Elaeisguineensis* to *Sterculia tragacantha* included in group 4.

The phylogenetic representation in Figure 8 displays all species included in the analysis from the Umuikwu Forest Anam (UFA) based on species abundance data. The dendrogram shows several distinct clusters, with close clusters such as *Sterculia tragacantha* and *Glyphae brevis* merging at a low height, indicating a high degree of similarity. Additionally, *Garcinia kola* and *Daniella oliveri* also merged at a low height, suggesting they are closely related. Intermediate clusters had *Hildegardiabarteri, Chrysophyllumalbidum,* and *Pterocarpus soyauxii* as examples; we can see that these species have moderate similarities as they merge at an intermediate height. Far-off clusters had species that merged at a higher height, like *Elaeisguineensis* and *Diospyros zenkeri,* showed notable distinctions from other species in their cluster. Several different groups were identified by additional results at a height of roughly 10 units of rescaled distance. *Hannoaklaineana, Glyphyae brevis, Tabernaemontanapachysiphon,* and *Sterculia tragacantha* were among the species that made up Group 1. Members of Group 2 include species such as *Daniellaoliveri* and *Garciniakola.* Group 3 species from*Hildegardiabarteri* to *Monodoratenuifolia* are included in this larger cluster while group 4 is large and includes *Elaeisguineensis* and *Naucleadiderrichii.*

Based on the dendrograms of the three sites, it can be observed that most species exhibit a similar cluster at lower heights. This suggests that there is fierce competition among the species for resources in the forest, such as light, water, and nutrients. This could be the cause of the majority of tree and shrub taxa's low abundance and dispersion in the forest, since taxa with high survival thresholds in competitive environments tend to predominate. Furthermore, because these species fight to survive only to be destroyed by fire or other natural disasters, which reduces their population in the forest, human interference may also be the cause of the low species diversity of the majority of families in the forest sites under study. One of the most important conservation tasks is to let forest tree and shrub species flourish naturally without being cut down.

In order to protect threatened plant taxa, an understanding of the phylogenetic relationships within a community of plants is useful for studying biodiversity, community structure, and ecological interactions. As a result, conservation efforts can benefit closely related species within the same cluster. Phylogenetically diverse forests are more resistant to environmental changes, according to studies [51], [52]. To sum up, a comprehensive understanding of forest ecosystems is possible when phylogenetic diversity is taken into account in addition to species richness and functional diversity. It maintains the complex web of life, fosters resilience, and directs conservation efforts.

5.0 CONCLUSION

We examined functional traits such as leaf area, leaf dry mass, and specific leaf area. These traits are thought to influence ecosystem processes including nutrient cycling, carbon sequestration, and habitat provision. The diversity of functional traits examined in this study provides valuable insights into ecosystem functioning. Therefore, researchers and other stakeholders can use this information to model carbon sequestration, nutrient cycling, and other ecosystem services. With regard to conservation and biodiversity protection, the findings of this study can serve as a guide for conservation policies and practices in Anambra State. Policymakers can use this information to designate protected areas, enforce sustainable land use, and prevent deforestation.

REFERENCES

1. Linnaeus C. Systemanaturae, 10th edn. Holmiae: ImpensisLaurentiiSalvii. 1758.
2. Barnosky AD, Matzke N, Tomiya S, Wogan GO, Swartz B, Quental TB, Marshall C, McGuire JL, Lindsey EL, Maguire KC & Mersey B. Has the Earth’s sixth mass extinction already arrived? Nature. 2011; 471 (7336): 51–57.
3. Carmona CP, Tamme R, Pärtel M, De Bello F, Brosse S, Capdevila P, González RM, González-Suárez M, Salguero-Gómez R, Vásquez-Valderrama M, Toussaint A. Erosion of global functional diversity across the tree of life. Sci. Adv. 2021; 7:1-13.
4. Pardini R, Bueno ADA, Gardner TA, Prado PI, Metzger JP. Beyond the fragmentation threshold hypothesis: regime shifts in biodiversity across fragmented landscapes. PLoS One. 2010; 5: Article e13666.
5. Rigueira DMG, da Rocha PLB, Mariano-Neto E. Forest cover, extinction thresholds and time lags in woody plants (Myrtaceae) in the Brazilian Atlantic Forest: resources for conservation. Biodiversity Conservation. 2013; 22:3141–3163.
6. Mcdowell NG, Allen CD, Anderson-teixeira K, Aukema BH, Bond-lamberty B, Chini L, Clark JS, Dietze M, Grossiord C, Hanbury-brown A, Hurtt GC, Jackson RB, Johnson DJ, Kueppers L, Lichstein JW, Ogle K, Poulter B, Pugh TAM, Seidl R, Turner MG, Uriarte M, Walker AP, Xu C. Pervasive shifts in forest dynamics in a changing world. Science. 2020; 368:1-10.
7. Swenson NG. The role of evolutionary processes in producing biodiversity patterns, and the interrelationships between taxonomic, functional and phylogenetic biodiversity. American Journal of Botany. 2011; 98: 472–480.
8. Cadotte MW, Carscadden K, Mirotchnick N. Beyond species: Functional diversity and the maintenanceof ecological processes and services. Journal of Applied Ecology. 2011; 48: 1079–1087.
9. Andrade ER, Jardim JG, Santos BA. Effects of habitat loss on taxonomic and phylogenetic diversity of understory Rubiaceae in Atlantic forest landscapes. Forest Ecological Management. 2015; 349:73–84.
10. Liu Y. Community assembly after long-term fragmentation: a case study of tropical rainforest in Xishuangbanna, south-west China. Plant Ecological Diversity. 2016; 9:55-62.
11. Santo-Silva EE, Santos BA, Arroyo-Rodríguez V, de Melo FPL, Faria D, Cazetta E, Mariano-Neto E, Hernandez-Ruedas M, Tabarelli M. Phylogenetic dimension of tree communities reveals high conservation value of disturbed tropical rainforestsDiversity Distributions, pp. 776-790. 2018.

12. Flynn DFB, Mirotchnick N, Jain M, Palmer MI, and Naeem S. Functional and phylogenetic diversity as predictors of biodiversity-ecosystem-function relationships. Ecology. 2011; 92: 1573–1581.
13. Suárez-Castro AF. et al. Correlations and variance among species traits explain contrasting impacts of fragmentation and habitat loss on functional diversity. – Landscape Ecol. 2020; 35: 2239–2253.
14. Zambrano J, Cordeiro NJ, Garzon C, Yeager L, Fortunel C, Ndangalasi HJ, Beckman NG. Investigating the direct and indirect effects of forest fragmentation on plant functional diversity. PLoS One, pp. 1-16. 2020.
15. Döbert TF, Webber BL, Sugau JB, Dickinson KJM, Didham RK. Logging increases the functional and phylogenetic dispersion of understorey plant communities in tropical lowland rain forest. *Journal of* Ecology. 2017; 105:1235-1245.
16. Ernoult A, Tremauville Y, Cellier D, Margerie P, Langlois E, Alard D. Potential landscape drivers of biodiversity components in a flood plain: past or present patterns? Biological Conservation. 2006; 127:1-17.
17. Reis IP, Rocha-santos L, Leal A, Faria D, Mielke MS. Landscape Forest Loss Changes Sunfleck Dynamics in Forest Fragments of Southern Bahia, Brazil.Journal of Tropical Ecology. 2021; 37 (2):64 – 71.
18. Cerqueira AF, Rocha-Santos L, Benchimol M. Habitat loss and canopy openness mediate leaf trait plasticity of an endangered palm in the Brazilian Atlantic Forest. Oecologia. 2021; 196:619–631.
19. Cadotte MW, Cardinale BJ & Oakley TH. Evolutionary history and the effect of biodiversity on plant productivity. Proceedings of the National Academy of Sciences of the United States of America. 2008; 105:17012-17017.
20. Petchey OL and Gaston KJ. Functional diversity: back to basics and looking forward. Ecol. Lett. 2006; 9:741–758.
21. Villeger S, Mason NWH and Mouillot D. New multidimensional functional diversity indices for a multifaceted framework in functional ecology. Ecology. 2008; 89:2290–2301
22. Dehling DM, Jordano P, Schaefer HM, Böhning-Gaese K and Schleuning M. Morphology predicts species' functional roles and their degree of specialization in plant-frugivore interactions. Proc. B., 2016; 283:2015-2444.
23. Mokany K, Ash J and Roxburgh S. Functional identity is more important than diversity in influencing ecosystem processes in a temperate native grassland. Journal of Ecology. 2008; 96: 884–893.
24. Gagic V, Bartomeus I, Jonsson T, Taylor A, Winqvist C, Fischer C. Functional identity and diversity of animals predict ecosystem functioning better than species-based indices. Proc. R. Soc. B., 2015; 282:2014-2620.
25. Díaz S andCabido M. “Vive la différence: Plant Functional Diversity Matters to Ecosystem Processes.” Trends in Ecology & Evolution. 2001; 16(11): 646–655.
26. Hooper DU, Chapin JJ, Ewel A, Hector P, Inchausti S, Lavorel JH. “Effects of Biodiversity on Ecosystem Functioning: A Consensus of Current Knowledge.” Ecological Monographs. 2005; 75(1): 3–35.
27. Cavender-Bares J, Kozak KH, Fine PVA, Kembel SW. The merging of community ecology and phylogenetic biology. Ecol. Lett., 2009; 12: 693–715.
28. Gillon J and Yakir D. Influence of Carbonic anhydrase activity in terrestrial vegetation on the ^{18}O content of atmospheric CO_2. Science. 2001; 291: 2584–2587.
29. Edwards EJ, Still CJ, Donoghue MJ. The relevance of phylogeny to studies of global change. Trends EcolEvol.,2007; 22: 243–249.
30. Willis CG, Ruhfel B, Primack RB, Miller-Rushing AJ, Davis CC. Phylogenetic patterns of species loss in Thoreau’s woods are driven by climate change. P Natl Acad Sci-Biol,2008; 105: 17029–17033.
31. Davis CC, Willis CG, Primack RB, Miller-Rushing AJ. The importance of phylogeny to the study of phenological response to global climate change. Philo TR Soc B, 2010; 365: 3201–3213.
32. Molnár AV, Tökölyi J, Végvári Z, Sramkó G, Sulyok J. Pollination mode predicts phenological response to climate change in terrestrial orchids: a case from central Europe. Journal of Ecology. 2012; 100: 1141–1152.
33. Nowak RS, Ellsworth DS, Smith SD. Functional responses of plants to elevated atmospheric CO_2 - do photosynthetic and productivity data from FACE experiments support early predictions? New Phytology. 2004; 162: 253–280.
34. Curtis PS and Wang XZ. A meta-analysis of elevated CO_2 effects on woody plant mass, form, and physiology. Oecologia. 1998; 113: 299–313.
35. Cramer W, Bondeau A, Woodward FI, Prentice IC, Betts RA. Global response of terrestrial ecosystem structure and function to CO_2 and climate change: results from six dynamic global vegetation models. Global Change Biol., 2001;7: 357–373.

36. Pearson RG, Dawson TP. Predicting the impacts of climate change on the distribution of species: are bioclimate envelope models useful? Global Ecology and Biogeography. 2003; 12: 361–371.
37. Esther A, Groenveld J, Enright NJ, Miller BP, Lamont BB. Sensitivity of plant functional types to climate change: classification tree analysis of a simulation model. J. Veg Sci.,2010; 21: 447–461.
38. Cadotte MW, Dinnage R & Tilman D. Phylogenetic diversity promotes ecosystem stability. Ecology. 2012; 93(sp8):S223–S233.
39. Cornelissen JHC, Lavorel S, Garnier E, Diaz S, Buchmann N, Gurvich DE, Reich PB, Ter Steege H, Morgan HD, Van Der Heiden MGA, Pausas JG &Poorter H. A handbook of protocols for standardized and easy measurements of plant functional traits worldwide. Australian Journal of Botany. 2003; 51:335–380.
40. Angiosperm Phylogeny Group. An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG III. Botanical Journal of the Linnean Society. 2009; 161:105–121.
41. Webb CO, Donoghue MJ. Phylomatic: tree assembly for applied phylogenetics. Molecular Ecology Notes.2005; 5: 181–183.
42. Mason NWH, Mouillot D, Lee WG and Wilson JB. Functional richness, functional evenness and functional divergence: the primary components of functional diversity. Oikos. 2005; 111: 112-118.
43. Walker B, Kinzig A and Langridge J. Plant attribute diversity and ecosystem function: The nature and significance of dominant and minor species. Ecosystems. 1999; 2: 95-113.
44. Petchey OL and Gaston KJ. Functional diversity (FD), species richness and community composition. Ecol. Lett.,2002; 5: 402-411.
45. Mason NWH, MacGillivray K, Steel JB. An index of functional diversity. J. Veg. Sci.,2003; 14: 571-578.
46. Hulot FD, Lacroix G, Lescher-Moutoue FO. Functional diversity governs ecosystem response to nutrient enrichment. Nature. 2000; 405: 340-344.
47. Petchey OL. Integrating methods that investigate how complementarity influences ecosystem functioning. Oikos.2003; 101: 323-330.
48. Tilman D. Biodiversity: population versus ecosystem stability. Ecology. 1996; 77: 350-363.
49. Dukes JS. Biodiversity and invasibility in grassland microcosms. Oecologia. 2001; 126: 563-568.
50. Miguel, AM, Selmy GJ, Candy RM, Salvador Montiel AR and Juan MP. Continuous forest has greater taxonomic, functional and phylogenetic plant diversity than an adjacent naturally fragmented forest .Journal of Tropical Ecology. 2014; 30:323-333.
51. Santos BA, Arroyo-Rodr´Iguez V, Moreno CE&Tabarelli M. Edge-related loss of tree phylogenetic diversity in the severely fragmented Brazilian Atlantic forest. PloS One. 2010; 5: e12625.
52. Arroyo-Rodr´Iguez V, Cavender-Bares J, Escobar F, Melo FPL, Tabarelli M & Santos B. Maintenance of tree phylogenetic diversity in a highly fragmented rain forest. Journal of Ecology. 2012; 100:702–711.