Floristic composition and stand structure in a tropical watershed forest: implications for biodiversity conservation.

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Abstract

Watershed ecosystems are unique ecologies that provide services and functions that are critical for the sustenance of natural water bodies as well as people that depend on them. However, there is limited information on plant species composition and distribution in most watershed forests in Nigeria. The watershed forest surrounding Arinta waterfall in Ipole Iloro, is an area protected by local communities, but facing anthropogenic threats associated with increased patronage from tourists from within and outside Nigeria. This study determined the floristic composition and vegetation structure in the Arinta watershed forest, using a stratified sampling technique. Nine sample plots, each 20 m by 20 m, were laid along three horizontal strata from the river valley upwards at 456 m, 470 m and 489 m above sea level. Within each sample plot, all plant forms were identified and enumerated, while growth variables like diameter and total height were measured for tree species. The species diversity indices were determined for all tree species encountered. Ninety two plant species from 51 families were found in the watershed ecosystem. These included 48 trees, 12 shrubs, 12 lianas, 16 herbs, 1 grass and 3 fern species. Ceiba pentandra was the most dominant species with an Importance Value Index (IVI) of 43.54% while Chrysophyllum albidum was the least (IVI = 0.78%). Fabaceae family had the highest species representation (14.13%) in the plant population. Shannon Wiener diversity index was 3.28, while the species evenness was 0.85. Approximately 64% of the tree species population had heights <10 m, while only 0.2% had heights >30 m. Similarly, tree species in diameter class 1 – 10 cm had the highest population of 630 wildlings/saplings ha^{-1}. The high floristic composition indicated the need for the conservation of the watershed which provides both protective and productive functions for the environment as well as the local community.

Keywords: Nigeria, Ipole Iloro, Arinta waterfall, ecotourism, watershed forest

Introduction

A watershed is an area of land that drains water, sediments and dissolved materials to a common receiving body or outlet. This vegetation area forms the drainage of streams or rivers and reduces flooding and erosion damages, while providing clean water and opportunities for recreation. Watersheds improve the structure and function of wetlands and wildlife habitats associated with them. Invariably, watersheds help to enhance the quality of life and the environment of adjoining communities (Aju, 2017; Asinwa *et al.*, 2018). These forests are unique vegetative features used to define the boundaries of ecosystems and they play a vital role in the biogeochemical cycles that occur on both the terrestrial and aquatic parts of the ecosystem. The woody plant species found in watershed forests influence soil and hydrological processes such as erosion control, soil and water quality enhancement, increment of water volume, stream flow stabilization, sediment distribution as well as control (Hans *et al.*, 2007; Aju, 2017; Manik and Sidle, 2018).

Arinta watershed forest is a naturally occurring forest growing on steep, weathered, sedimentary rock in the lowland rain forest zone of Nigeria. This dense, humid rainforest is rich in biological diversity and serves as a natural seed bank for important tree species. The waterfall is a tourist site in Ekiti state, Nigeria. The government and community have been making efforts towards the development of this natural monument into an Ecotourism Centre, which could boost revenue generation. However, a direct impact of urbanization and infrastructural development is the destruction of the watershed vegetation. Although, recreation and tourism infrastructure within protected areas may be limited, the creation of tracks, trails, roads, lookouts, fixed campsites and other types of accommodation affect biodiversity. It becomes pertinent that the plant diversity in the Arinta watershed vegetation be evaluated to assist in future conservation and sustainable management of the site, particularly with the impending pressure that may result from several disturbances due to the commercialization of the site for ecotourism activities (Ijasan and Izobo-Martins, 2012; Olaniyi *et al*., 2015). Hence, this study determined plant species diversity, composition and distribution along the Arinta waterfall topography in order to provide information on the current status of the watershed forest.

Materials and Methods

Site description

Arinta watershed forest is in Ekiti West Local Government Area, Efon Alaaye, Ekiti state, Nigeria. It lies along latitudes 7° 33.02' N and 7° 33.50' N; longitudes 4°55.1' E and 4°55.58' E. It has a rhythmically undulating hilly terrain with elevation that ranges from 455 m – 495 m above sea level (Figure 1). The 4.5 ha watershed forest experiences two distinct seasons: rainy (from April – October), and dry (from November - March). The forest grows on a long steep valley formed out of a weathered mountain and it is dominated by broadleaf hardwood trees which form dense layered stands. The waterfall that emanates from the rocky outcrop is the source of a stream which supplies most of the water requirements of residents of Ipole Iloro town in Ekiti state, Nigeria. Farming and logging are prohibited within the watershed forest based on customary laws.

Sampling procedure

Nine sample plots, each measuring 20 m by 20 m, were laid along the slope of the watershed forest in three horizontal strata from the river valley upwards: lower stratum (456 m) middle stratum (470 m), and upper stratum (489 m). The stratification was based on the elevation, which was determined using a Hand-held Gemini Sotrex GPS. The sample plots were laid at 30 m interval within each stratum, and a distance of 40 m was used to separate the strata from one another. All trees, shrubs, lianas and herbs within each sample plot were identified and enumerated with the help of a plant taxonomist as well as with reference to relevant local plant manuals and Flora of West Tropical Africa (Hutchinson and Dalziel, 1994). Voucher specimens of plants that could not be identified were collected, preserved and taken to the Herbarium of the Forestry Research Institute of Nigeria, Ibadan, Nigeria for identification. The diameter at breast height (dbh) ≥ 10 cm and total height of tree species were measured. A 2 m-wide strip or belt transect (1 m on either side of the centre line) was laid at the middle of each sample plot, and used to determine shrubs, wildlings, herbs and lianas with collar diameter ≥ 2 cm (Olajuyigbe and Adaja, 2014).

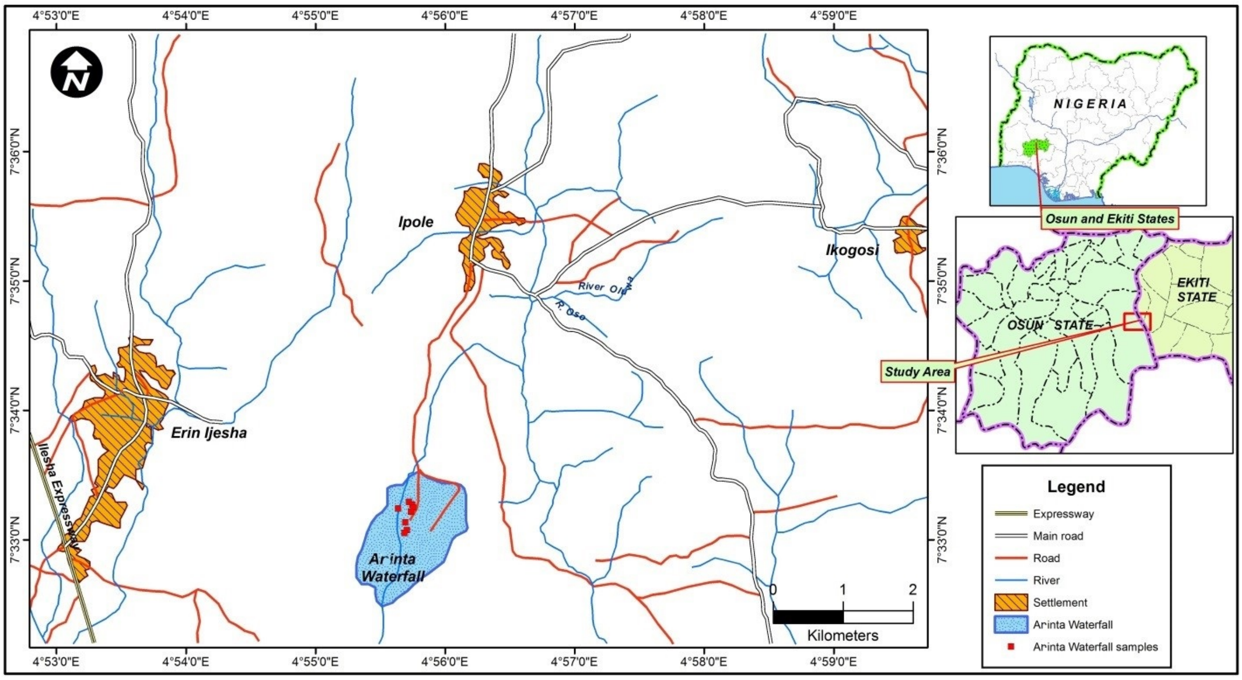

Figure 1. Arinta waterfall Ipole Iloro, Ekiti State, Nigeria (Inset: Maps of Nigeria and Ekiti state)

The Basal Area BA (m^2), of all the trees in the sample plots were calculated using Equation 1 following the method of Adekunle *et al.* (2013):

$$BA = \frac{\pi D^2}{4} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where D = diameter at breast height (m) and π = (3.142). The plot basal area for each of the sample plots was obtained by summing all BA of trees in the plot while the mean plot basal area (BA_p) was calculated as the sum of basal areas of all sampled plots divided by the number of plots. Basal area per hectare was obtained by multiplying mean plot basal area with the number of 20 m ×20 m plots in 1 hectare.

The tree volume was estimated by multiplying the individual tree BA with total height. The plot volume was estimated by summing up individual tree volumes and then the mean volume per plot and per hectare was determined.
All tree species were assigned to families and number of species in each family was obtained and used to determine tree species diversity indices. The following diversity indices were used to obtain tree species abundance/richness and evenness within the watershed forest.
I. Relative frequency of tree species was obtained using Equation 2:

$$RF = \frac{F_i}{F_n} \times 100\% \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where RF= Relative Frequency, F_i = number of plots where species i was encountered, and F_n = total frequency of all species.
II. Species Relative Density (RD) was obtained using Equation 3:

$$RD = [\frac{n'}{N}] \times 100\% \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where RD = Relative Density, n_i = number of individuals of species i and N = total number of individuals in the entire population.
III. Relative dominance was obtained using Equation 4:

$$RD_O = \frac{(\sum BA_i \times 100)}{\sum BA_n} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Where RD_o = relative dominance, BA_i = basal area of all individual trees belonging to a particular species i and BA_n = Total basal area of all species encountered.
IV. Shannon Wiener diversity index was estimated using equation 5:

$$H^1 = \sum_{i=1}^{S} pi\ Ln\ pi \ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Where; H^1 = the Shannon Wiener diversity index, S = total number of species in the watershed forest, pi = the proportion of a species to the total number of plants in the watershed forest and Ln = the natural logarithm.
V. Species evenness (E) was determined using Shannon's Equitability index (E_H) (Equation 6):

$$E_H = \frac{H^1}{L_n(S)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

Where; S = the total number of species in the watershed forest.
VI. Importance Value index (IVI): was calculated by summing the Relative density, Relative dominance and Relative frequency.

Results

A total of 92 plant species belonging to 82 genera from 51 families were identified in the watershed forest ecosystem (Table 1). These comprised six plant forms (48 trees, 12 shrubs, 12 lianas, 16 herbs, 1 grass and 3 ferns) with trees being the most dominant species. The mean number of trees per plot was 34 ± 3.61, while the mean plot basal area and mean tree volume per plot were 1.24 ± 0.25 m^2 and 16.82 ± 4.33 m^3, respectively (Table 2). It was estimated that density of trees > 10 cm dbh were 850 ± 90.14 trees ha^{-1}, with a basal area and total volume of 31.06 ± 6.30 m^2 ha^{-1} and 420.61 ± 108.36 m^3 ha^{-1}, respectively in the forest.

Table 1: Floristic composition and plant form at Arinta Watershed forest, Ipole Iloro, Ekiti state, Nigeria.

Species	Family	Common name
	Ferns	
Cyclosorus afer (Christ.) Ching	Thelypterideae	Cyclosorus fern
Nephrolepis biserrata (Sw.) Schott	Polypodiaceae	Giant sword fern
Nephrolepis undulata (Afzel. ex Sw.) J.Sm	Oleandraceae	Annual sword fern
	Grass	
Axonopus compressus (Sw.) P. Beauv.	Poaceae	Blanket grass
	Herbs	
Acanthus montanus (Nees) T. Anders.	Acanthaceae	False Thistle

Ageratum conyzoides L.	Asteraceae	Billy Goat Weed
Alternanthera sessilis (L) DC.	Amaranthaceae	Sessile joyweed
Aspilia africana (Pers.) C. D. Adams	Compositae	Haemorrhage plant
Colocasia esculenta (L.) Schott.	Araceae	Elephant ears
Commelina lagosensis C.B. Clarke	Commelinaceae	Day flower
Ipomoea reticulata O'Donell	Convolvulaceae	Morning glory weed
Ipomoea involucrata P. Beauv.	Convolvulaceae	Morning glory weed
Mucuna pruriens (L.) DC.	Fabaceae	Velvet beans
Plumbago zeylanica L.	Plumbaginaceae	Ceylon leadwort
Phyllanthus amarus Schum. & Thonn.	Euphorbiaceae	Hurricane weed
Physallis angulata L.	Solanaceae	Wild goose berry
Scoparia dulcis L.	Scrophulariaceae	Sweet broom weed
Smilax kraussiana Meisn.	Smilacaceae	Smilax
Thaumatococcus daniellii (Benn.) Benth.	Marantaceae	Miraculous berry
Tragia vogelii Keay	Euphorbiaceae	Nose burn
	Lianas	
Alafia barteri Oliv.	Apocynaceae	Guinea fowl's crest
Asparagus africanus Lam.	Asparagaceae	Climbing African asparagus
Canthium venosum (Oliv.) Hiern	Rubiaceae	Raisin-fruit Keetia
Chasmanthera dependens Hochst.	Menispermaceae	Chasmanthera
Dioclea reflexa Hook F.	Fabaceae	Marble's vine
Dioscorea dumetorum (Kunth) Pax.	Dioscoreaceae	African bitter yam
Gnetum africanum Welw.	Gnetaceae	Wild spinach
Momordica foetida Schumach.	Cucurbitaceae	Ejirin (Yoruba)
Parquetina nigrescens (Afzel.) Bullock	Apocynaceae	Ewe Ogbo (Yoruba)
Piper guineense Schum. & Thonn.	Piperaceae	West African black pepper
Quisqualis indica Linn.	Combretaceae	Rangoon creeper
Saba thompsonii (A.Chev.) Pichon	Apocynaceae	Komero-akowa
	Shrubs	
Alchornea cordifolia (Schumach. & Thonn.) Müll Arg.	Euphorbiaceae	Christmas bush
Alchornea laxiflora (Benth.) Pax & K Hoffm.	Euphorbiaceae	Three-veined bead string
Annona reticulata Linn.	Annonaceae	Bullock's heart
Bridelia atroviridis Müll. Arg.	Euphorbiaceae	Rare forest bridelia
Bridelia micrantha (Hochst.) Baill.	Euphorbiaceae	Bridelia
Cnestis ferruginea Vahl. ex. DC.	Connaraceae	Short pod
Combretum micranthum G. Don	Combretaceae	Bush tea
Icacina trichantha Oliv.	Icacinaceae	Gbegbe (Yoruba)
Rauvolfia vomitoria Afzel.	Apocynaceae	Swizzle stick
Rinorea elliotii Engl.	Violaceae	Iparoko
Sphenocentrum jollyanum Pierre	Menispermaceae	Akerejupon
Xylopia aethiopica (Dunal) A. Rich	Annonaceae	West African pepper tree

	Trees	
Antiaris toxicaria Lesch.	Moraceae	Antiaris
Albizia adianthifolia (Schumach.) W. F. Wight	Fabaceae	Flat crown
Albizia gummifera (J. F. Gmel.) C. A. Sm.	Fabaceae	Peacock flower
Alstonia boonei De Wild.	Apocynaceae	Alstonia
Anthocleista djalonensis A. Chev.	Loganiaceae	Cabbage tree
Artocarpus communis J. R. Forst. & G. Forst.	Moraceae	Breadfruit
Bombax buonopozense P. Beauv.	Bombacaceae	Wild kapok
Brachystegia eurycoma Harms	Fabaceae	Achi
Brachystegia kennedyi Hoyle	Fabaceae	Okwen
Ceiba pentandra (L.) Gaertn.	Malvaceae	White silk cotton tree
Chrysophyllum albidum G. Don.	Sapotaceae	White star apple
Cola afzelii (R. Br.) Mast.	Sterculiaceae	Kola nut
Cola gigantea A. Chev.	Sterculiaceae	Witch's bread
Cordia millenii Bak.	Boraginaceae	Drum tree
Dialium guineense Willd.	Fabaceae	Velvet tamarind
Diospyros mespiliformis Hochst.	Ebenaceae	West African Ebony
Distemonanthus benthamianus Baill.	Fabaceae	African satinwood
Dracaena arborea (Willd.) Link	Dracaenaceae	Dragon tree
Dracaena mannii Baker	Dracaenaceae	Small-leaved dragon tree
Elaeis guineensis Jacq.	Arecaceae	Oil palm
Entandrophragma angolense (Welw.) C. DC.	Meliaceae	Tiama mahogany
Erythrophleum suaveolens (Guill. & Perr.) Brenan	Fabaceae	Sasswood tree
Ficus exasperata Vahl.	Moraceae	Forest sandpaper fig
Funtumia elastica (Preuss.) Stapf.	Apocynaceae	Rubber tree
Garcinia kola Heckel.	Clusiaceae	Bitter kola
Hollarrhena floribunda (G. Don) Dur. & Schinz.	Apocynaceae	False rubber
Khaya ivorensis A Chev.	Meliaceae	African Mahogany
Lecaniodiscus cupanioides Planch.	Sapindaceae	Limba
Massularia acuminata (G. Don) Bullock	Rubiaceae	Maiden's breasts tree
Milicia excelsa (Welw.) C. C. Berg	Moraceae	Iroko (Yoruba)
Musanga cecropioides R. Br.	Cecropiaceae	Umbrella tree
Myrianthus arboreus P. Beauv.	Cecropiaceae	Giant yellow mulberry
Napoleonaea vogelii Hook. & Planch.	Lecythidaceae	Wallia
Newbouldia laevis Seem.	Bignoniaceae	Akoko tree
Pentaclethra macrophylla Benth.	Fabaceae	Oil of bean tree
Piliostigma thonningii (Schumach.) Milne-Redh	Fabaceae	Camel's foot tree

Piptadeniastrum africanum (Hook. F.) Brenan	Fabaceae	African greenheart
Pterygota macrocarpa K Schum.	Sterculiaceae	African pterygota
Pycnanthus angolensis (Welw.) Warb.	Myristicaceae	African nutmeg
Ricinodendron heudelotii (Baill.) Pierre	Euphorbiaceae	African wood-oil nut tree
Senna siamea (Lam.) Irwin & Barneby	Fabaceae	Siamese tree
Spondias mombin Linn.	Anacardiaceae	Hog plum
Sterculia rhinopetala K Schum.	Sterculiaceae	Brown sterculia
Sterculia tragacantha Lindl.	Sterculiaceae	African tragacanth
Terminalia superba Engl. et Diels	Combretaceae	White afara
Trema micrantha (L.) Blume	Ulmaceae	Nettle tree
Trema orientalis (Linn.). Blume	Ulmaceae	Charcoal tree
Zanthoxylum zanthoxyloides (Lam.) Zepern. & Timler	Rutaceae	Toothache bark

There was no tree species in the emergent layer (i.e. trees >50 m in height) with the tallest trees being *Ceiba pentandra* (32 m) and *Cordia millenii* (30 m). The understory represented 34.8% of the tree population, while 1.1% of the tree population were in the lower canopy (canopy height = 20 to 30 m). Only 4 individual tree species (0.2%) were in the upper canopy (Figure 2).

Table 2: Strata and plot distribution of tree species (>10 cm dbh) in Arinta watershed forest at Ipole Iloro Ekiti, Ekiti state, Nigeria. (Stratification levels were at the lower (456 m), middle (470 m) and upper (489 m) sections of the watershed forest, each plot was 20 m by 20 m in size)

Stratum	Plot number	Number of trees (per plot)	Basal area (m^2/plot)	Tree volume (m^3/plot)
1	1	35	1.02	12.84
1	2	26	3.09	49.45
1	3	37	1.54	19.95
2	1	34	0.72	8.33
2	2	23	0.67	7.91
2	3	19	0.70	9.18
3	1	50	0.92	9.59
3	2	32	1.16	16.85
3	3	50	1.36	17.31

Tree species in the lowest diameter class (1 – 10 cm) had the highest population (630 wildlings/saplings ha^{-1}) while those in the highest diameter class (>50 cm) had the lowest (25 trees ha^{-1}). Nevertheless, trees with diameter class >50 cm, had the highest basal area and dominated the watershed vegetation. The increase in area sampled had a positive effect on the number of species with additional taxa being encountered with increased sampling intensity. However, the species-area curve (Figure 4) did not level off to a horizontal asymptote after the maximum number of species (77) had been encountered. Hence, the slope of the curve did not approach zero (R^2 = 0.98, $P < 0.0001$).

The herb population was dominated by species such as *Alternanthera sessilis, Ageratum conyzoides, Phyllanthus amarus,* while climbers were dominated by *Alafia barteri*, *Chasmanthera* *dependens*, *Quisqualis indica*, and *Saba thompsonii*. In addition, the dominant shrubs included *Bridelia atroviridis, Rauvolfia vomitoria* and *Combretum micranthum.*

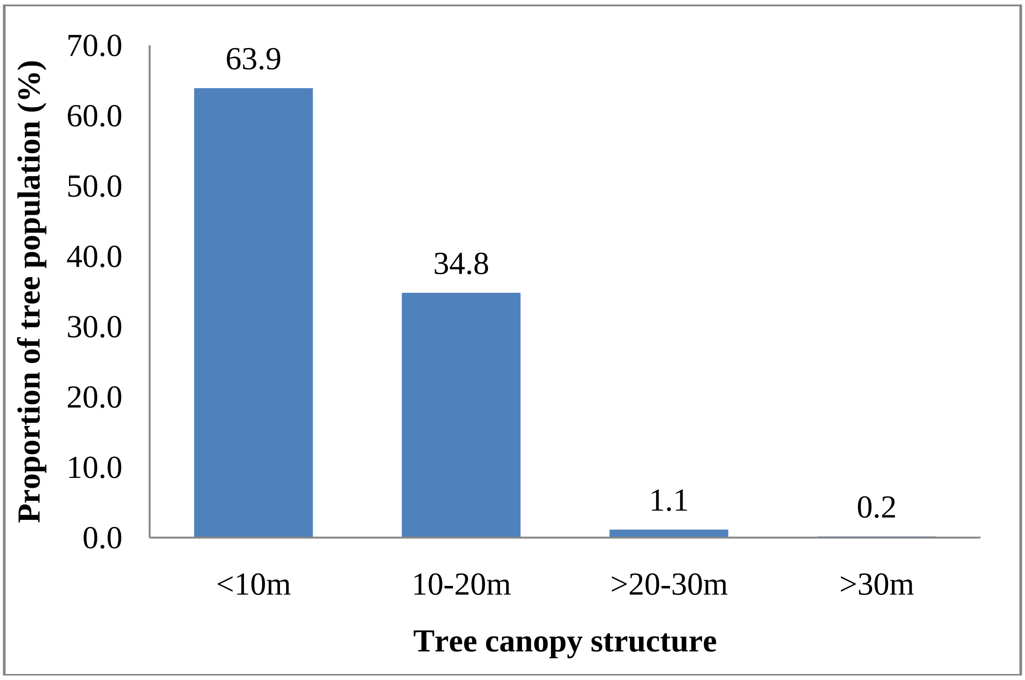

Figure 2: Population of trees and canopy structure of Arinta watershed forest in Ipole Iloro, Ekiti state, Nigeria .

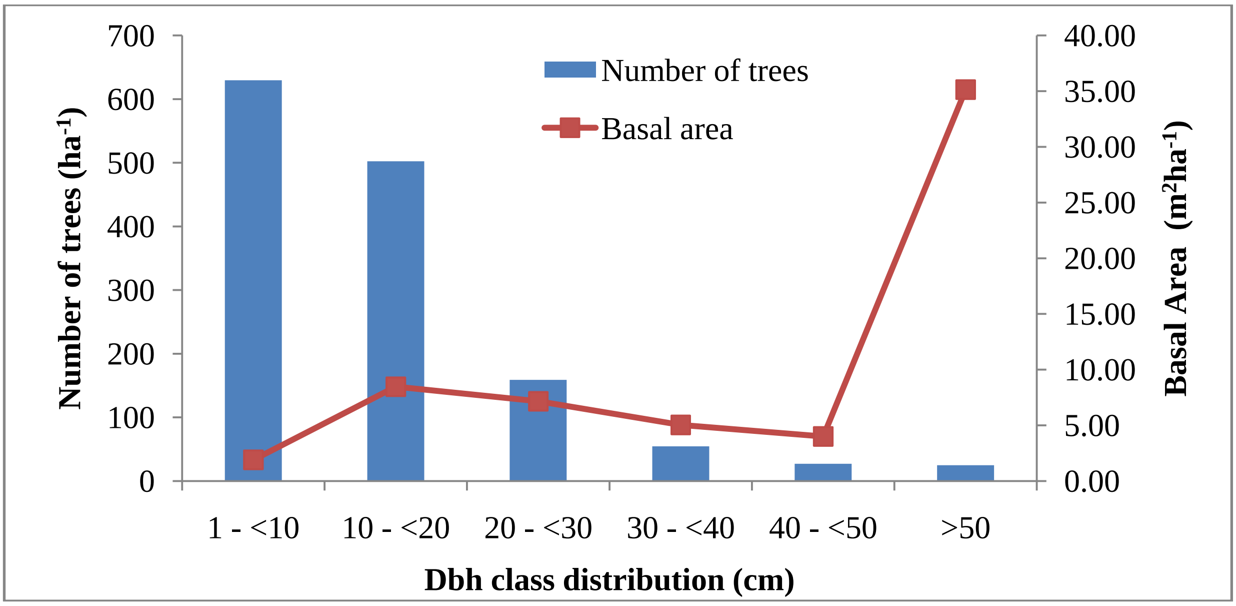

Figure 3: Tree basal area and diameter class distribution of tree species at Arinta watershed forest, Ipole Iloro, Ekiti State, Nigeria (bars represent number of trees; line represent basal area)

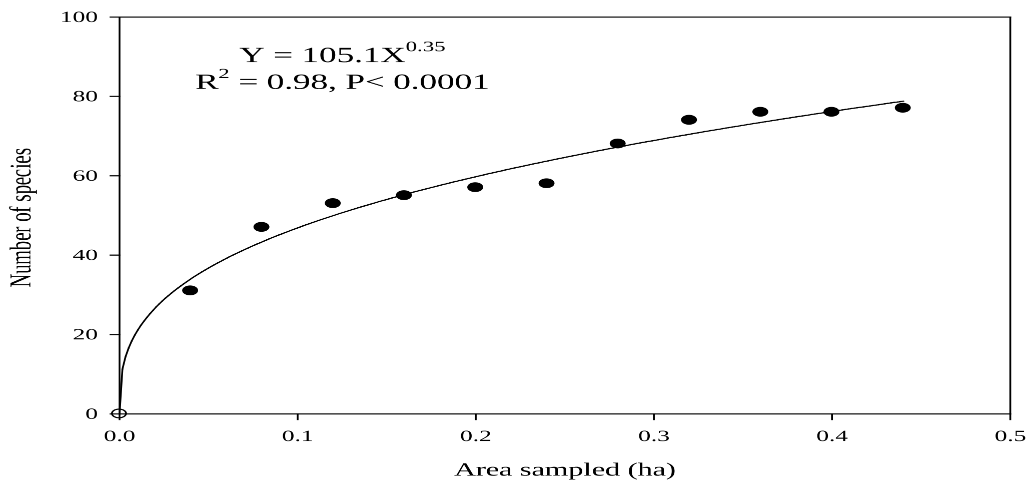

Figure 4: Plant species-area curve at Arinta watershed forest, Ipole Iloro, Ekiti State, Nigeria (taxa presence increased with sampling intensity).

Table 3: Tree growth variables and species diversity indices at Arinta watershed forest, Ipole Iloro, Ekiti State, Nigeria.

Species	Basal area (m^2)	Volume (m^3)	Relative Frequency (%)	Relative density (%)	Relative dominance (%)	IVI	H^1
Albizia adianthifolia	1.58	23.23	4.12	5.57	6.05	15.74	0.16
Albizia gummifera	0.06	0.66	1.18	0.54	0.22	1.94	0.03
Alstonia boonei	0.25	3.70	2.94	0.90	0.94	4.78	0.04
Anthocleista djalonensis	0.09	0.90	2.94	1.62	0.33	4.88	0.07
Antiaris toxicaria	0.43	5.64	4.12	3.05	1.66	8.83	0.11
Artocarpus communis	0.60	8.08	1.18	1.44	2.28	4.90	0.06
Bombax buonopozense	0.19	2.59	1.76	1.26	0.74	3.76	0.06
Brachystegia eurycoma	0.01	0.07	0.59	0.54	0.06	1.18	0.03
Brachystegia kennedyi	0.02	0.21	0.59	0.18	0.07	0.84	0.01
Ceiba pentandra	11.16	357.26	0.59	0.18	42.77	43.54	0.01
Chrysophyllum albidum	0.003	0.02	0.59	0.18	0.01	0.78	0.01
Cola afzelii	0.01	0.08	1.18	0.90	0.06	2.13	0.04
Cola gigantea	0.11	1.10	1.18	1.08	0.41	2.66	0.05
Cordia millenii	1.02	24.55	5.88	4.49	3.92	14.29	0.14
Dialium guineense	0.85	8.27	4.71	9.52	3.25	17.48	0.22

Diospyros mespiliformis	0.30	4.38	1.18	0.54	1.15	2.87	0.03
Distemonanthus benthamianus	0.02	0.20	0.59	0.18	0.09	0.86	0.01
Dracaena arborea	0.07	0.79	0.59	0.72	0.26	1.57	0.04
Dracaena mannii	0.01	0.05	0.59	0.54	0.05	1.17	0.03
Elaeis guineensis	0.03	0.06	0.59	0.18	0.12	0.89	0.01
Entandrophragma angolense	0.01	0.05	0.59	0.18	0.02	0.79	0.01
Erythrophleum suaveolens	0.04	0.47	0.59	0.36	0.14	1.09	0.02
Ficus exasperata	0.09	1.21	2.35	1.80	0.34	4.48	0.07
Funtumia elastica	0.48	5.80	3.53	3.59	1.84	8.96	0.12
Garcinia kola	0.06	0.50	0.59	0.18	0.21	0.98	0.01
Hollarrhena floribunda	1.25	15.46	5.88	8.26	4.77	18.91	0.21
Khaya ivorensis	0.24	4.05	0.59	0.54	0.92	2.04	0.03
Lecaniodiscus cupanioides	0.01	2.84	4.71	6.10	0.02	10.83	0.17
Massularia acuminata	0.06	0.38	0.59	2.87	0.23	3.69	0.10
Milicia excelsa	1.49	36.42	2.35	0.90	5.72	8.97	0.04
Musanga cecropioides	0.05	0.77	0.59	0.36	0.20	1.14	0.02
Myrianthus arboreus	0.20	3.11	2.35	0.90	0.78	4.03	0.04
Napoleonaea vogelii	0.06	0.40	3.53	3.41	0.23	7.17	0.12
Newbouldia laevis	0.02	0.13	1.18	0.72	0.06	1.96	0.04
Pentaclethra macrophylla	0.61	17.22	1.18	0.54	2.32	4.03	0.03
Piliostigma thonningii	0.37	4.34	4.71	3.23	1.41	9.34	0.11
Piptadeniastrum africanum	1.02	16.70	4.71	3.77	3.90	12.38	0.12
Pterygota macrocarpa	1.01	11.04	4.12	10.41	3.87	18.40	0.24
Pycnanthus angolensis	0.15	1.71	2.35	2.51	0.58	5.45	0.09
Ricinodendron heudelotii	0.04	0.23	0.59	2.69	0.14	3.43	0.10
Senna siamea	0.02	0.15	0.59	0.18	0.07	0.84	0.01

Spondias mombin	1.30	18.74	5.88	7.54	4.99	18.41	0.19
Sterculia rhinopetala	0.03	0.21	0.59	0.72	0.10	1.41	0.04
Sterculia tragacantha	0.01	0.11	0.59	0.18	0.05	0.82	0.01
Terminalia superba	0.04	0.56	0.59	0.18	0.14	0.91	0.01
Trema micrantha	0.30	6.65	2.94	1.44	1.16	5.53	0.06
Trema orientalis	0.18	2.88	1.76	0.90	0.70	3.36	0.04
Zanthoxylum zanthoxyloides	0.17	2.55	2.94	1.97	0.65	5.57	0.08
Total	**26.10**	**596.52**					**3.28**

The tree species with the highest relative frequencies were *Cordia millenii* (5.88%), *Hollarrhena floribunda* (5.88%) and *Spondias mombin* (5.88%) while the lowest were *Brachystegia eurycoma* (0.59%), *Brachystegia kennedyii* (0.59%), *Ceiba pentandra* (0.59%), *Chrysophyllum albidum* (0.59%), *Distemonanthus bentamianus* (0.59%), *Dracaena arborea* (0.59%), *Dracaena mannii* (0.59%), *Elaeis guineensis* (0.59%), *Entandrophragma angolensis* (0.59%), *Erythrophleum suaveolens* (0.59%), *Garcinia kola* (0.59%), *Khaya ivorensis* (0.59%), *Massullaria acuminata* (0.59%), *Musanga cecropioides* (0.59%), *Ricinodendron heudelotii* (0.59%), *Senna siamea* (0.59%), *Sterculia rhinopetala* (0.59%), *Sterculia tragacantha* (0.59%) and *Terminalia superba* (0.59%). *Ceiba pentandra* had the highest basal area (11.16 m^2), relative dominance (42.77%), total volume (357.26 m^3) and Importance Value Index (IVI: 43.54%). *Hollarrhena floribunda* was the next species with a high IVI (18.91%), while *Chrysophyllum albidum* had the lowest IVI (0.78%). The individual tree species with the highest number of stems were *Pterygota macrocarpa* (131 trees ha^{-1}), *Dialium guineensis* (120 trees ha^{-1}) and *Hollarrhena floribunda* (104 trees ha^{-1}). The Shannon Wiener diversity Index (H^1) was 3.28 while the species evenness (E_H) was 0.85. Fabaceae (14.13%), Apocynaceae (7.61%), Euphorbiaceae (7.61%) and Moraceae (4.35%) were the most dominant families and had the highest species representation in the watershed forest (Figure 5).

Discussion

Plant species richness provides an insight to the structural and functional complexities in an ecosystem. The species diversity gives an indication of the ecological gradients and the environmental quality of forests (Gillespie *et al.*, 2004; Olajuyigbe and Adaja, 2014). Hence, the assessment of the floristic composition of sensitive ecosystems such as watersheds is essential for the development of proper management, sustainability and conservation strategies (Cannon *et al.*, 1998; Addo-Fordjour *et al.*, 2009). Unfortunately, very few studies have focused on the plant species diversity and structure in Nigerian watersheds (Olaniyi *et al.*, 2015; Asinwa *et al.*, 2018).
The 92 plant species from 82 genera (Table 1) encountered in the Arinta watershed forest suggests a relatively conserved ecosystem through the activities of the adjoining community (Ipole Iloro town). This is because the people identify with the environmental, economic and social importance of the watershed ecosystem.

The 48 tree species recorded indicate a high structural diversity in the watershed ecosystem (Gillespie *et al.*, 2004; Long and Shaw, 2009; Sambas and Siregar, 2017). Although, the tree species richness in this study was higher, it was similar to the 36 tree species identified by Olaniyi

et al. (2015), in the same ecosystem. It was also similar to the tree species richness reported for the Ogun river watershed forest (43) in Ogun state, Nigeria (Asinwa *et al.*, 2018).
The high species richness observed is rare with many Nigerian watershed forests already degraded through anthropogenic activities (Aju, 2017). For instance, Ogbemudia *et al.* (2013) reported only 43 plant species in a disturbed watershed forest in Akwa Ibom state, Nigeria. It has been suggested that the vegetation at Arinta waterfall, protects the water source from erosion and landslide events. Hence, the waterfall needs to be officially designated as a protected area despite the government's interest in ecotourism development (Ijasan and Izobo-Martins, 2012; Olaniyi *et al.*, 2015).

The family dominance in the forest followed the pattern reported for other tropical rainforest ecosystems in Nigeria. Previous studies on rainforests ecosystems in Nigeria have reported that Fabaceae, Euphorbiaceae and Sterculiaceae are the most dominant families in such forests (Adekunle *et al.*, 2013; Olajuyigbe and Adaja, 2014; Olajuyigbe and Jeminiwa, 2018). Fabaceae is the third largest plant family and also the most common in the tropical rainforest comprising trees, shrubs, lianas and herb species (Burnham and Johnson, 2004; Mahbubur-Rahman and Ismot-Ara-Parvin, 2014). The dominance and abundance of species from the Fabaceae family could also be partly, attributed to the method of seed dispersal by species in this family. These plants use an explosive mechanism for releasing seeds from their pods and these seeds are then wind dispersed to great distances from their origin. To this end, seeds travel far from the mother tree and germinate under favourable conditions in the rich luxuriant watershed ecosystem (Ihenyen *et al.*, 2009).

The species-area curve gives an inference to ecosystem biological processes such as disturbances, competition, and division of niches. In this study, the species-area curve which predicts extinctions due to biotic collapse (loss of species due to reduction in habitat area), approached the asymptotic level after 77 species had been encountered suggesting the maximum value for plant species richness in the watershed forest (Palmer and White, 1994; Hambler and Canney, 2013; Olajuyigbe and Adaja, 2014). Hence, the quantitative sampling of the vegetation was representative, with a minimum area of 0.44 ha revealing the maximum representation of floristic similarity and species diversity among sample plots. .

The diameter distribution of trees formed an upside down 'J' curve which is typical of tropical rainforests undergoing dynamic changes. The abundance of trees in the lower diameter size categories (630 wildings/saplings ha^{-1} in < 10cm and 500 trees ha^{-1} in >10 − 20 cm) indicates the propensity for natural regeneration of the tree community (Olajuyigbe and Adaja, 2014; Sambas and Siregar, 2017). On the other hand, trees in the >50 cm diameter size category dominated the spatial distribution with basal area of 35.14 m^2ha^{-1}. The mean basal area (31.06 ± 6.30 m^2 ha^{-1}) compared favourably with reported mean tree basal area (25 m^2 ha^{-1}) for fully stocked forests (Alder and Abayomi, 1994). The emergent layer was absent in the vertical stratification of the watershed forest with the tallest trees (>30 m) in the upper canopy representing only 0.2% of the tree population while 1.1% of the trees were in the lower canopy (10 - 20 m) (Figure 2). This was probably due to the steep topography which limits the ability of trees to grow without constraints in watershed forests (Sambas and Siregar, 2017).

The Shannon Wiener diversity index (H^1) has been used for characterizing community diversity in tropical watershed forest ecosystems (Olaniyi *et al.*, 2016; Asinwa *et al.*, 2018). The H^1 obtained for Arinta watershed forest (3.28) was within the upper limit of 1.5–3.5 reported for Nigerian rainforests (Adekunle and Olagoke, 2008; Olajuyigbe and Adaja, 2014). The species equitability index (E_H = 0.85) was also similar to values reported by Adekunle and Olagoke, (2008) in natural forest (0.86) of Ondo state, Nigeria. This suggests that there is even distribution of species in the watershed forest.

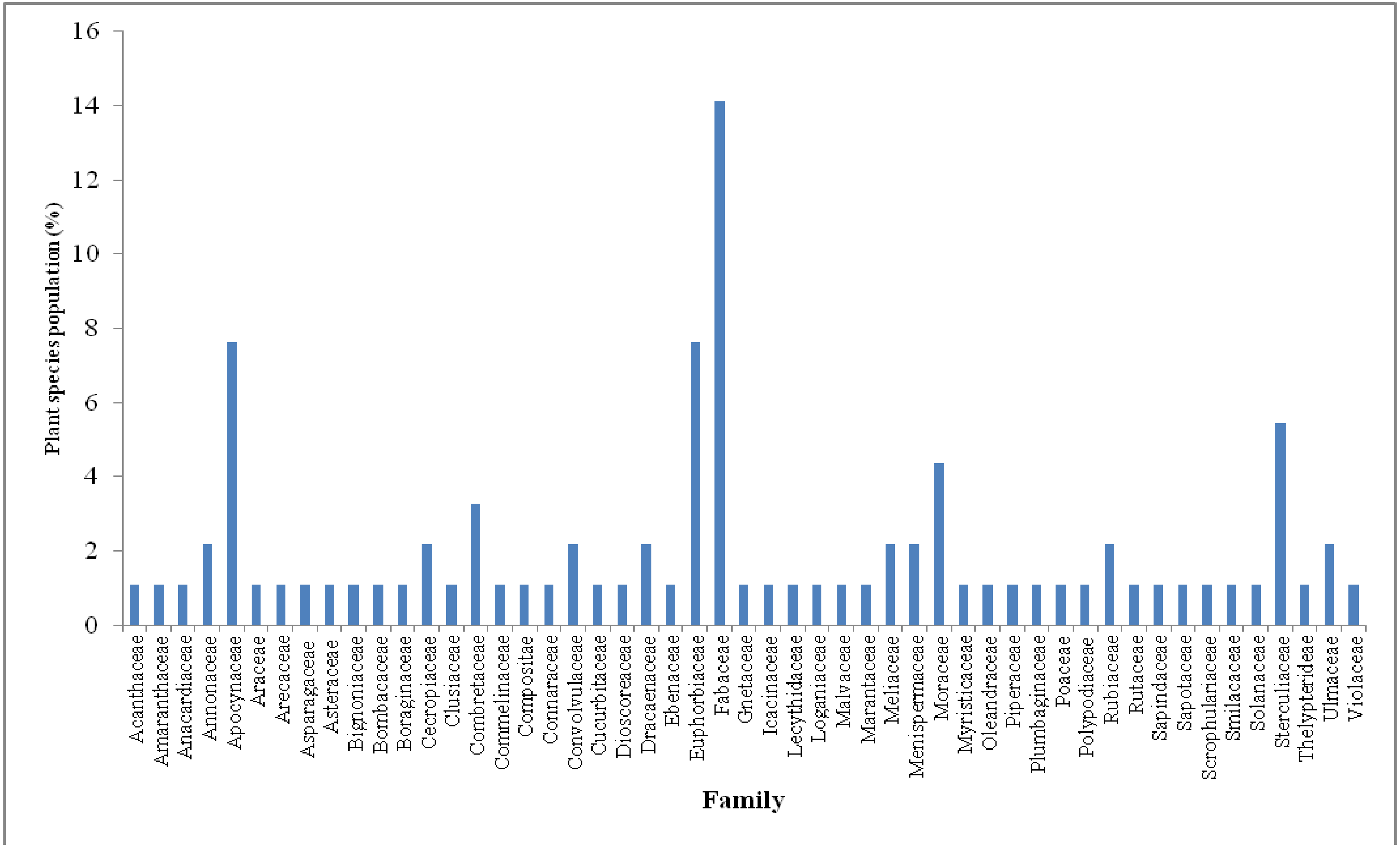

Figure 5: Family dominance at Arinta watershed forest, Ipole Iloro, Ekiti state, Nigeria.

The Importance Value Index (IVI) combines the attributes of relative density, frequency and dominance (Table 3). It highlights the relative importance of a species to its community (Anning *et al.*, 2009). In this study, *Ceiba pentandra,* which is an indicator species in high humidity ecologies, had the highest IVI (43.32%). This pioneer species has also been reported as a dominant species in various types of forest including watershed and gallery ecosystems (Burnham and Johnson, 2004).

Although the local people were committing a lot of effort towards the protection and conservation of Arinta watershed forest, there is need for government legislation that would ensure protection and sustainable management of this sensitive ecosystem. Scientific studies such as the current study would provide empirical information on vulnerable plant communities and the habitats that require conservation (Wang *et al.*, 2002; Sambas and Siregar, 2017). Arinta watershed forest can serve as an *in situ conservation* area for many plant species that have already become locally rare or scarce in degraded forests of Nigeria. Some of these species include; *Afzelia africana*, *Antiaris africana, Brachystegia spp., Cordia millenii, Dialium guineense, Entandrophragma spp., Khaya ivorensis, Milicia excelsa, Pterygota macrocarpa, Sterculia setigera, Terminalia superba* and *Triplochiton scleroxylon* (Olajuyigbe and Adaja, 2014).

Watershed forests help to maintain hydrological cycles by absorbing excess precipitation and reducing the speed of rainfall runoffs, while recharging aquifers, maintaining stream flows, filtering and preventing pollutants from entering water bodies, which serve as habitat for aquatic life (Aju, 2017). They provide recreational and ecotourism opportunities for local communities while ensuring that good quality water can be accessed by the people. Unfortunately, the ecosystem services are usually undervalued and this beclouds the general understanding of people on these essential life support services that are beneficial to man and the environment. Hence, there is need for awareness creation on the invaluable quality of watershed ecosystems and why they need to be conserved, especially with the increased impacts of the changing global climate.

Conclusion

Arinta watershed forest is a highly diverse ecosystem with high potential for biodiversity conservation in Nigeria's tropical rainforest. The conscious efforts of the Ipole Iloro community coupled with the difficult terrain had ensured the preservation of this cultural heritage. There were 92 plant species with Fabaceae family dominating the population. The canopy structure lacked an emergent layer, with *Ceiba pentandra* being the indicator species. Arinta watershed ecosystem had created a refuge for many plant species that have become scarce in most Nigerian forests. However, there is need for laws that would designate protection area status on the watershed vegetation especially with increasing ecotourism activities in the area.

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