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Floristic composition, diversity and community structure in a secondary rainforest in Ibadan, Nigeria

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Secondary forests may act as buffer area and serve as reservoir for biotic components that are lost from primary forest due to anthropogenic disturbances. This study investigated the floristic composition, diversity and community structure of Cocoa Research Institute of Nigeria (CRIN), Idi-Ayunre, Ibadan, Nigeria. Twenty-five main plots (each 50 m × 50 m) were randomly mapped out to enumerate tree species, five 10 m × 10 m sub-plots were systematically mapped out within each main plot to enumerate shrubs and three quadrats (1 m × 1 m) were laid in each sub-plot to enumerate herbaceous species in Wet Season (WS) and Dry Season (DS). Relative Importance Value (RIV), Taxa, Individuals, Dominance, Shannon-Wiener, Equitability and Jaccard similarity index were determined. A total of 181 plant species from 145 genera and 54 families which included 63 trees, 33 shrubs and 85 herbaceous species were enumerated. In wet season, *Triplochiton scleroxylon*, *Lonchocarpus griffonianus* and *Chromolaena odorata* had the highest RIV while in dry season, *Terminalia superba*, *Lonchocarpus cyanescens* and *C. odorata* were the highest for trees, shrubs and herbs, respectively. Low dominance but high equitability and Shannon-Weiner values indicated inter-specificity among trees, shrubs and herbs. It was only in herbs that Jaccard-similarity was less than 100% across seasons. Resilience for keystone species conservation is possible due to flora species heterogeneity of the study site.

Key words: Forest ecosystem, biodiversity, anthropogenic activities, relative importance value, ecosystem services.

INTRODUCTION

Secondary forests constitute a large and growing component of forest cover and are crucial in the provision of various goods and services in the ecosystem (Jenkins and Schaap, 2018). Forest resources exploitation and associated industries create employment and revenue base which suggests its roles in socio-economic development policies (World Bank, 2016). Forest ecosystems provide habitat for biodiversity, provides food stuff and other important resources for humans to survive on land (Atomsa and Dibbisa, 2019). Since biodiversity occupies a crucial role in provision of goods and services for forest ecosystems, human activities through exploitation of some of the available goods and services symbolizes ecosystem degradation which is inimical to

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biodiversity conservation. The increasing exploitation of tropical rainforests for silviculture and anthropogenic activities such as habitation, agriculture and industry are devastating and of a great concern due to their ecological impacts (Monarrez-Gonzalez et al., 2020). It has been reported that conversion and degradation of forest for agriculture has destroyed about 55% of the world's original area of tropical moist forest leading to biodiversity loss across the world (Green et al., 2005; Awodoyin et al., 2013). Impact of forest conversions includes changes in soil, vegetation, hydrological functions, climate change and depletion of natural resources and biodiversity (Jenkins and Schaap, 2018). Halting anthropogenic activities such as timber harvesting, logging, agriculture and promotion of sustainable forestry management practices would contribute to the resilience of a secondary forest in biodiversity and other ecosystem services (Olajuyigbe and Jeminiwa, 2018). However, adequate monitoring, protection and sustainable management of a tropical secondary rainforest require a good knowledge of flora component, diversity and structure (Fang Zeh et al., 2019). Information on the floristic composition and structure of the secondary forest is key to understanding the larger dynamics of forest area and finding key elements of plant diversity (Akinyemi and Oke, 2014; Van Rooyen et al., 2016). Therefore, changes in species distributions, composition and abundance are measured through biological components of an ecosystem (O'Connor et al., 2017). Awodoyin et al. (2013) enumerated flora species composition, diversity and community structures in Cocoa plots in Nigeria, as an inventory of Nigeria flora status due to agriculture. Studies on floristic assessment will assist in the current state and future prediction of an ecosystem. This study enumerated composition, diversity and community structure of herbs, shrubs and trees in secondary forest of Cocoa Research Institute of Nigeria (CRIN), Idi-Ayunre, Ibadan, Nigeria.

MATERIALS AND METHODS

The study was carried out in the secondary Forest of Cocoa Research Institute of Nigeria (CRIN), Idi-Ayunre, Ibadan, Oyo State, Nigeria (Figure 1). The CRIN was established by the Federal Government of Nigeria through the Nigeria Research Institute in 1964 (Atanda, 1977). The CRIN estate falls within the transitory rainforest-savanna vegetation of Nigeria and located within coordinates 07° 12.157' and 07° 13.260' North and 03° 51.093' and 03° 52.290' East (Obatolu, 2014). Sampling was conducted in 25 quadrats that were randomly located and established using Global Positioning System (GPS; Garmin Map78 model).

The geographical coordinates of each main quadrat (50 m × 50 m) (Figure 2) were recorded using Garmin map 78 GPS in a total area of 482.63 ha of CRIN stratified zones. The number of plots selected in each zone depended upon area of the forest fragment, and it was 2, 3, 4, 5 or 6 sampled plots per zone. A total of 25 main quadrats (50 m × 50 m) were established per season. The quadrat size established for the enumeration depended on plant life form. Trees were enumerated within each main quadrat (50 m × 50 m). Shrub species were enumerated in five sub-quadrats (10 m × 10 m each) laid within each main quadrat. The sub-quadrats were located at the four corners and one at the centre of the main quadrat. A total of 125 sub-quadrats per season were established for enumeration of shrubs. Three sub-sub-quadrats of 1 m × 1 m each were located randomly in each sub-quadrat to enumerate herbaceous species. Hence, a total of 375 sub-sub-quadrats were laid to collect data on herbaceous species per season. A complete inventory of plant species was done in the main quadrat (trees), sub-quadrat (shrubs) and sub-sub-quadrats (herbaceous) and was carried out between July and August for the wet season and January to February for the dry season. The trees and shrub plants were identified by their local and scientific names with the help of a forester who speaks the local language (Yoruba) and the herbaceous were identified with the help of a flora on West African weeds (Akobundu et al., 2016) and those that could not be identified were collected each day, preserved and taken to the CRIN Laboratory for identification with the help of a taxonomist.

Data analysis

From the data, measure of relative importance value for each species in each site was determined as mean of relative density and relative frequency for each species following the methods in Kent and Coker (1992) and Awodoyin and Egberongbe (2010).

$$[(RD + RF)/2] \times 100$$

where RD=Relative Density and RF=Relative Frequency.

$$RD = (d/D) \times 100$$

where d = the density of a species; D = total density of all species.

$$RF = (f/F) \times 100$$

where f = the frequency of a species; F = total frequency of all species.

Also, the biological community structure as informed by the ecological diversity of the plant species was determined by alpha and beta diversity. The alpha diversity, which is the diversity of species within a particular community, was determined by Species Richness (R), Shannon-Wiener (H`), Evenness (J) and Dominance (D) indices using Paleontological Statistics (PAST) software version 3.0 (Hammer, 2011). The beta diversity, which is the expression of between-habitat diversity, was determined by the Jaccard index of similarity (Spellerberg, 1993).

Species richness is the total number of species occurring within a specified area of the community.

The Shannon-Wiener index of species diversity is calculated as:

$$H` = -\sum_{i=0}^{n} Pi.\, lnpi$$

where pi is the proportion which is the number of individuals in a species (n) in relation to the total number of all individuals in a community (N):

$$pi = n/N$$

ln is the Naperian logarithm $ln = 2.303 \times \log_{10}$

The species equitability index (J) is calculated as:

$$J = H`/lnS$$

where H` is Shannon-Wiener index and S is total number of species in the community. The Dominance index (D) is calculated as:

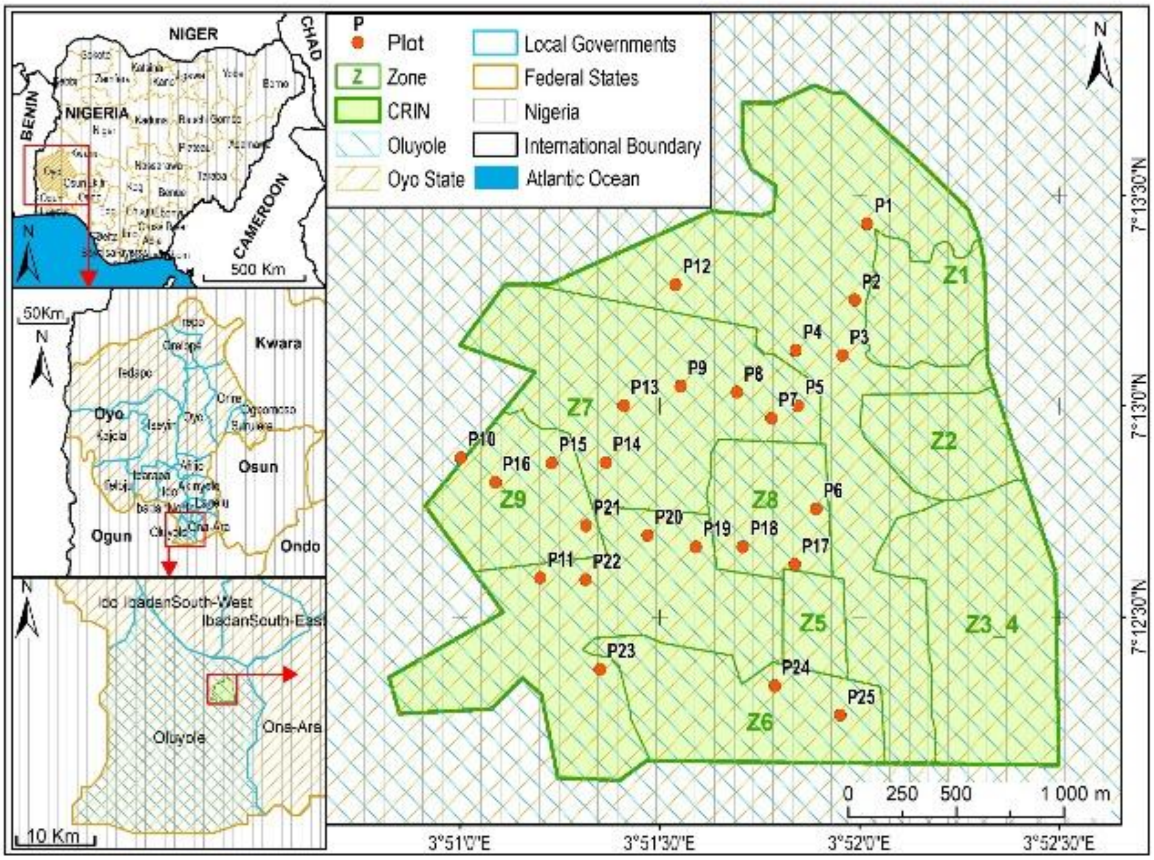

Figure 1. Selected plots and transects in CRIN Headquarters Ibadan, Oluyole LG and Oyo State widen and inset map of Nigeria.

$D = \sum (n/N)^2$

where n is number of individuals of a particular species and N is the total number of individuals found in the community.
Jaccard index of community similarity (SCj) is calculated as:

$SCj\ (\%) = W/(A+B-W) \times 100$

where W is the number of common species, A is the number of species in community A, and B is the number of species in community B.

RESULTS AND DISCUSSION

The result of enumeration gave a total number of 181 plant species including 85 herbaceous (Table 1), 33 shrubs (Table 2) and 63 trees (Table 3) belonging to 145 genera and 54 families (21 for herbaceous, 17 for shrubs and 29 for trees) in both wet and dry seasons. Among these families, Fabaceae had the highest number of species (25) followed by Poaceae (20 species), Asteraceae and Rubiaceae had 12 species each, Euphorbiaceae (11 species), Malvaceae (10 species), Apocynaceae (seven species), Moraceae and Solanaceae families had six species each, Cyperaceae (five species), Acanthaceae and Commelinaceae had four species each, Combretaceae, Nyctaginaceae, Sapindaceae and Ulmaceae had three species each.

Eleven families namely Amaranthaceae, Boraginaceae, Connaraceae, Convolvulaceae, Irvingiaceae, Meliaceae, Rutaceae, Tiliaceae, and Verbenaceae had two species each while the remaining 23 families like Agavaceae, Anacardiaceae, Annonaceae, Bignoniaceae, Bombacaceae, Capparidaceae, Clusiaceae, Cucurbitaceae, Dennstaedtiaceae, Dioscoreaceae, Icacinaceae, Lamiaceae, Loganiaceae, Myristicaceae, Meliaceae, Musaceae, Ochidaceae, Pedaliaceae, Phyllanthaceae, Piperaceae, Portulacaceae, Sapindaceae, and Sapotaceae had one species each.

The micro-habitat of CRIN secondary forest was closely similar in vegetation types and species composition but varied slightly in individual species (structure) enumerated in the wet and dry seasons. The species composition in shrubs and trees species was similar in the wet and dry season, but there was difference in the herbaceous species composition in the wet and dry seasons. The finding of this study indicated high species richness and abundance for herbs, shrubs and trees species but herbaceous had the highest

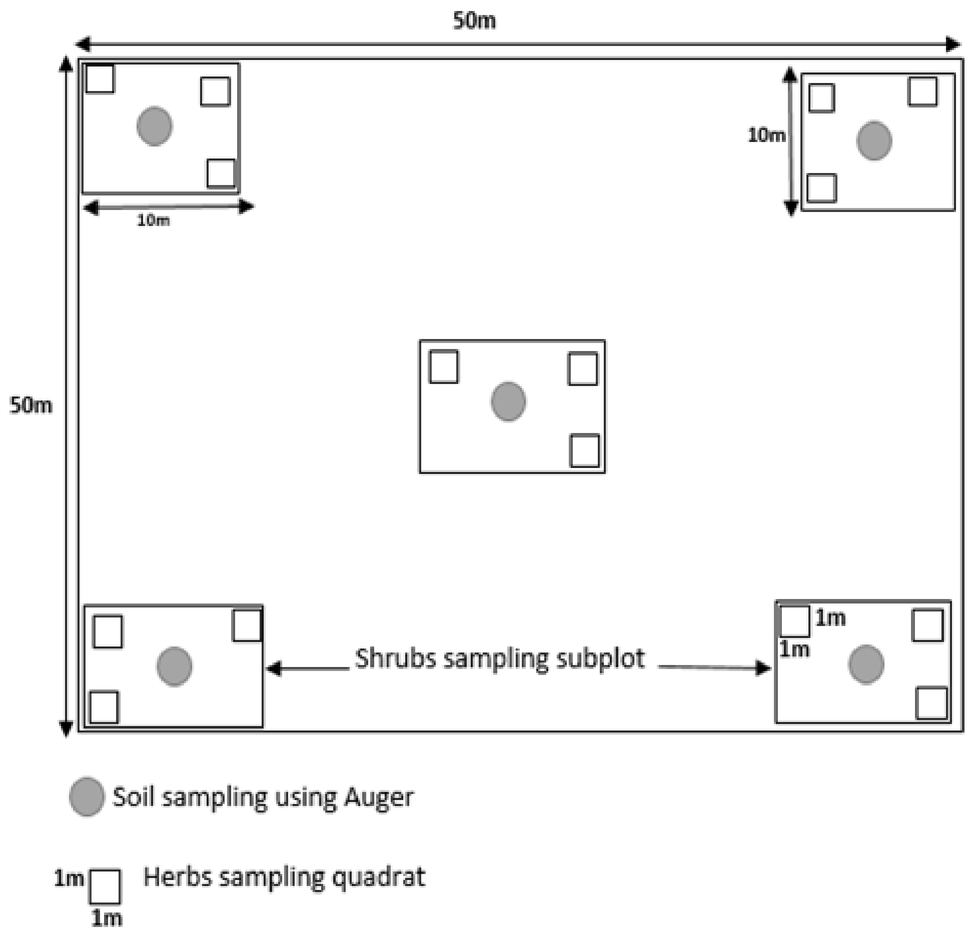

Figure 2. Sampling layout for trees, shrubs and herbs enumeration at Cocoa Research Institute of Nigeria, CRIN.

species richness and abundance. This was similar to the findings of Komolafe et al. (2017) who opined that Ibodi forest of Southwest Nigeria contains 47 herbs and 93 trees while Tang et al. (2010) reported high species composition of 222 plant species in secondary vegetation communities of China comprising 113 herbaceous species, 109 woody species (trees, shrubs, and lianas) with 79 families and 183 genera. The high species composition and abundance may be attributed to human perturbations in the CRIN forest. This was similar to the assertion of Mishra et al. (2008) that herbaceous species dominance over shrubs and trees composition in a disturbed forest may be attributed to the presence of anthropogenic activities including the harvest of food tree plantations (Oluwatosin and Jimoh, 2016). Also, Kessler et al. (2005) attributed the presence of high number of herbaceous flora in a recovery forest to the presence of few mature trees, which allows the penetration of light thereby promoting the growth of light-loving plants known as heliophytes (Bobo et al., 2006; Awodoyin et al., 2013). The most abundant number of herbaceous species was found in Poaceae and Asteraceae in both seasons while Rubiaceae and Fabaceae contained the most abundant shrub species and Fabaceae, Moraceae and Malvaceae were the most abundant tree species. The abundance of Asteraceae in both wet and dry season conforms to the study of Awodoyin et al. (2013) who reported that Asteraceae was found to be among the highest families of herbs in cocoa agroforest of tropical rainforest zone of Nigeria and Ahmed et al. (2015) who reported same for semi-desert region of Egypt. Notwithstanding the number of species identified for herbs, shrubs and trees, the abundance of individuals for most herb species was higher in the wet season than the dry season, which may be attributed to adequate moisture availability.

Relative importance values of herbaceous species in wet and dry seasons of CRIN Secondary Forest, Ibadan, Nigeria

The result showed the herbaceous species that were enumerated (85 species in wet season and 69 species in dry season). Among the herbaceous species identified,

Table 1. Annual and Perennial herbaceous species composition on selected plots in Secondary Forest of Cocoa Research Institute of Nigeria, Ibadan.

S/N	Family	Species	Life forms
1	Acanthaceae (4)	*Acanthus montanus* (Nees) T. Anders	Perennial
		Asystasia gangetica (linn.) T. Anders	Perennial
		Blepharis maderaspatensis (Linn.) Heine & Roth	Perennial
		Rungia dimorpha S. Moore	Perennial
2	Amaranthaceae (2)	*Celosia argentea* L.	Perennial
		Pupalia lappacea (linn.) Juss.	Perennial
3	Asteraceae (12)	*Ageratum conyzoides* Linn.	Annual
		Aspilia africana (Pers.) C.D. Adams	Perennial
		Bidens pilosa Linn.	Annual
		Chromolaena odorata (L.) R.M. King & Robinson	Perennial
		Cleome rutidosperma D.C.	Annual
		Conyza sumatrensis (Retz.) walker	Annual
		Emilia coccinea (Sims) G. Don	Annual
		Melanthera scandens (Schum. &Thonn) Roberty	Perennial
		Sclerocarpus africanus Jacq.ex Murr.	Annual
		Synedrella nodiflora Gaertn.	Annual
		Tithonia diversifolia (Hermsl.) A. Gray	Annual
		Tridax procumbens Linn.	Perennial
4	Combretaceae (1)	*Combretum hispidum* Laws.	Annual
5	Commelinaceae (4)	*Aneilema beniniense* (P. Beauv.) Kunth	Perennial
		Commelina benghalensis L.	Perennial
		Commelina erecta L.	Perennial
		Palisota hirsuta (Thunb) K.Schum.	Perennial
6	Convolvulaceae (2)	*Ipomoea aquatica* Forsk	Perennial
		Ipomoea triloba Linn	Perennial
7	Cucurbitaceae (1)	*Momordica charantia* Linn.	Annual
8	Cyperaceae (5)	*Cyperus amabilis* Vahl	Annual
		Cyperus esculentus Linn.	Annual
		Cyperus rotundus Linn.	Annual
		Fuirena umbellata Rottb.	Perennial
		Mariscus longibracteatus Cherm.	Perennial
9	Dennstaedtiaceae (1)	*Pteridium aquilinum* (Linn.) Kuhn	Perennial
10	Dioscoreaceae (1)	*Tacca leontopetaloides* (L.)	Perennial
11	Euphorbiaceae (6)	*Croton lobatus* L.	Annual
		Euphorbia hirta Linn.	Annual
		Mallotus oppositifolius (Geisel.) Mull. Arg.	Annual
		Phyllanthus amarus (schum. & thonn.)	Annual
		Phyllanthus niruri (Schum. & Thonn.)	Annual
		Spurge heterophylla Linn.	Perennial
12	Fabaceae (7)	*Calopogonium mucunoides* Desv.	Perennial

Table 1. Contd.

		Chamaecrista mimosoides (L.)	Annual
		Crotalaria retusa Linn.	Annual
		Desmodium scorpiurus (Sw.) Desv.	Perennial
		Mimosa pudica Linn.	Perennial
		Schrankia leptocarpa DC.	Perennial
		Senna hirsuta (Linn.) Irwin & Barneby	Perennial
13	Lamiaceae (1)	*Solenostemon monostachyus* P. Beauv.	Annual
	Loganiaceae (1)	*Spigelia anthelmia* Linn.	Annual
14	Malvaceae (3)	*Abutilon mauritianum* (Jacq.)	Perennial
		Sida acuta Burn. F.	Perennial
		Sida linifolia Juss. Ex Cav.	Perennial
15	Nyctaginaceae (3)	*Boerhavia coccinea* Mill.	Perennial
		Boerhavia diffusa L.	Perennial
		Boerhavia erecta L.	Perennial
16	Pedaliaceae (1)	*Sesamum alatum* Thonning	Annual
17	Piperaceae (1)	*Peperomia pellucida* (L.) Kunth	Perennial
18	Poaceae (19)	*Andropogon tectorum* Schum. & Thonn.	Perennial
		Axonopus compresus (Sw.) P. Beauv.	Perennial
		Brachiaria deflexa (Schumach.) C. E. Hubbard	Annual
		Brachiaria falcifera (Trin.) Stapf	Annual
		Brachiaria lata (Schumach.) C.E. Hubbard	Annual
		Cynodon dactylon (Linn.) Pers.	Perennial
		Digitaria exilis (Kippist) Stapf.	Annual
		Digitaria horizontalis Willd.	Annual
		Eleusine indica (L.) Gaertn.	Annual
		Eragrostis tremula Steud.	Annual
		Imperata cylindrica (L.) Raeusch	Perennial
		Oplismenus burmannii (Retz.) P.Beauv.	Annual
		Panicum laxum Sw.	Annual
		Panicum maximum Jacq.	Annual
		Paspalum scrobiculatum Linn.	Perennial
		Perotis indica (Linn.) O. Ktze	Annual
		Setaria barbata (Lam.) Kunth	Annual
		Setaria longiseta P. Beauv.	Perennial
		Setaria megaphylla (Steud.) Dur. & Schinz	Perennial
19	Portulacaceae (1)	*Talinum fruticosum* (L.) Juss.	Perennial
20	Rubiaceae (6)	*Oldenlandia corymbosa* Linn.	Annual
		Richardia scarbra L.	Annual
		Spermacoce ocymoides Burm.F.	Annual
		Solanum macrocarpon L.	Perennial
		Solanum nigrum L.	Annual
		Solanum torvum Swartz	Perennial
21	Urticaceae (3)	*Laportea aestuans* (Linn.) Chew.	Annual
		Laportea avalifolia (Schum.) Chew	Annual

Table 1. Contd.

		Pouzolzia guineensis Benth.	Perennial
Total	21	85	Annual : 41 Perennial : 44

Chromolaena odorata had the highest Relative Importance Value (RIV) of 25.26% (WS) and 12.27% (DS), followed by *Cyperus rotundus* (8.13%) in wet, *Aspilia africana* (5.72%) in dry, *Setaria megaphylla* (5.14% in wet) and (1.31% in dry) (Table 4). The lowest RIV belongs to *Panicum maximum* with 0.03% in wet season and *Combretum hispidum* with 0.14% in dry season.

Table 5 shows the shrub species in both seasons. *Lonchocarpus griffonianus* had 8.8% RIV (the highest in wet season) and 7.8% of RIV in dry season (Table 5). *Lonchocarpus cyanescens* had 9.0% of RIV (the highest in dry season) and 8.5% of RIV in wet season. *Solanum erianthum* had 7.7 and 1.33% of RIV in wet and dry season while *Rauwolfia vomitoria* had 6.7 and 4.3% of RIV in dry and wet season, respectively. The lowest RIV belonged to *Dracaena deisteiliana* with 0.1% of RIV in wet and in dry season followed by *Keetia venosa* 0.5 and 0.7% of RIV in wet and dry season, respectively.

A total of sixty-three trees species were enumerated in the wet and dry seasons (Table 6). The most abundant species was *Triplochiton scleroxylon* with 5.64% of RIV (the highest in wet season) and 4.96% of RIV in dry season (Table 6). *Terminalia superba* followed with 5.66% of RIV (the highest in dry season) and 4.99% of RIV in wet season followed by *Pterygota macrocarpa* which had 3.91 and 3.97% of RIV in wet and dry season while *Cedrela odorata* had 1.31 and 1.32% of RIV in wet and dry season, respectively. The lowest common RIV (0.24%) in wet and dry season belonged to the four species namely *Afzelia africana*, *Brachyestegia eurycoma,* *Gambeya albida* and *Lecaniodiscus cupanioides*.

The heavy presence of *C. odorata* might have influenced the number of herbaceous species composition in the CRIN forest. The high occurrence of *C. odorata,* a ubiquitous species of disturbed forest in the rainforest supports the assertion of Oke and Isichei (1997) who reported that *C. odorata* is a common herb of tropical rainforest. The *C. odorata* like many in Asteraceae family has the peculiar intense competitive ability, fast growth, efficient seed dispersal mechanism and high regeneration rate. The invasion of the study site by *C. odorata* might have influenced the number of herbaceous species flora due to previous land-use change, especially deforestation for cultivation. This agrees with the findings of Agboola and Muoghalu (2015) that reported a decrease in plant species composition and diversity in sites invaded by *Tithonia diversifolia* and *C. odorata*.

The high number of Rubiaceae among shrub species composition in the secondary rainforest of CRIN was supported by Ndah et al. (2013) who mentioned that Rubiaceae was the most prominent family of shrub in species composition, diversity and distribution in a disturbed Takamanda Rainforest, South West, Cameroun. The RIV of *L. griffonianus* (Fabaceae) remains prominent in both wet and dry season but it was second in its occurrence to *L. cyanescens* (Fabaceae) in the dry season. *L. griffonianus* and *L. cyanescens* (Fabaceae) are pioneer species that have fast regeneration ability. They are usually abundant in disturbed forest or forest in their transition state (Bobo et al., 2006). However, the low number of *L. griffonianus* in the dry season may be its inability to tolerate vagaries of weather, resource and nutrient competition. This was supported by the findings of Ogwu et al. (2016) who reported that limited access to water resources may affect the survival of young trees (shrubs) in the dry season. Similarly*, L. cyanescens* which belongs to Fabaceae alongside *L. griffonianus* may be a better nitrogen pump in the dry season where the decomposition by microorganism would be low due to low humidity. In a tropical rainforest, some Fabaceae like *L. cyanescens* and *L. griffonianus* have root nodules that could sequester and fix atmospheric nitrogen into the soil with the aid of *Rhizobium*. This was corroborated by Chen (2006) who reported seasonal (water and temperature) influence on the performance of nitrogen fixation. Fabaceae had the highest number of tree species (12), followed by Moraceae and Malvaceae, each with six species. The high number of species composition of Fabaceae and Moraceae in Nigeria rainforest has widely been documented (Salami and Lawal, 2018). This aligns with the findings of Adekunle et al. (2010) and Adekunle (2016) who reported that families such as Sterculiaceae, Meliaceae, Moraceae and Ebenaceae dominate the tropical rainforest of southwest Nigeria. The ability of Moraceae to produce a large number of seeds and quickly establish itself may account for their high presence and this was confirmed by Deka et al. (2012). Also, the high species composition of Fabaceae may be attributed to high competitive ability for water and other growth resources (Ogwu et al., 2016). The trees with the highest RIV values in both wet and dry seasons were the most commonly found trees in the study site; *T.*

Table 2. Perennial shrubs species composition on selected plots in secondary Forest Cocoa Research Institute of Nigeria, Ibadan.

S/N	Family	Species composition	Life forms
1	Agavaceae (1)	*Dracaena deisteiliana* Engl	Perennial
2	Apocynaceae (3)	*Hunteria umbellata* (K.Schum) Hailier	Perennial
		Pleioceras barteri Baill.	Perennial
		Rauwolfia vomitoria Afzel	Perennial
3	Arecaceae (1)	*Elaeis guineensis* Jacq.	Perennial
4	Bignoniaceae (1)	*Markhamia tomentosa* (Benth) K.Schum ex Engl	Perennial
5	Capparidaceae (1)	*Euadenia trifoliata* Oliv.	Perennial
6	Connaraceae (2)	*Agelaea obligua* (P.Beauv.) Baill.	Perennial
		Cnestis ferruginea DC	Perennial
7	Euphorbiaceae (3)	*Alchornia cordifolia* (Schum. & Thonn.)	Perennial
		Jatropha curcas Linn.	Perennial
		Microdesmis puberula Hook. F. ex Planch	Perennial
8	Fabaceae (4)	*Acacia macrostachya* Reichenb. ex Benth.	Perennial
		Angylocalyx oligophyllus Bak. F.	Perennial
		Lonchocarpus cyanescens (Schum. & Thonn.) Benth	Perennial
		Lonchocarpus griffonianus (Baill.) Dunn.	Perennial
9	Icacinaceae (1)	*Icacinia trichanta* Oliv.	Perennial
10	Meliaceae (1)	*Trichilia prieuriana* A. Juss	Perennial
11	Musaceae (1)	*Musa paradisiaca* L.	Perennial
12	Ochidaceae (1)	*Rytiginia umbellata* Thom.	Perennial
13	Rubiaceae (8)	*Coffea canephora* Pierre ex A.Froehner	Perennial
		Corynanthe pachyceras K.Schum	Perennial
		Euclinia longifolia Salisb.	Perennial
		Keetia venosa (Oliv.) Bridson	Perennial
		Pavetta corymbosa (DC.) F.N. Williams	Perennial
		Psilanthus ebracteolatus (Hiern) Hiern.	Perennial
		Psychotria fimbriatifolia R.D. Good	Perennial
		Psychotria sciandephora Hiern	Perennial
14	Sapindaceae (1)	*Deinbollia pinnata* Schum. & Thonn.	Perennial
15	Solanaceae (2)	*Solanum erianthum* D. Don	Perennial
		Solanum torvum Sw	Perennial
16	Tiliaceae (2)	*Desplatsia subericarpa* Bocq.	Perennial
		Grewia mollis Juss.	Perennial
17	Verbanaceae (1)	*Clerodendron capitatum* Willd	Perennial
Total	17	34	34

scleroxylon (Malvaceae) and *T. superba* (Combretaceae). Therefore, trees with such economic importance to human may have suffered exploitation and responsible for the decline in the number of tree species in a secondary forest. This assertion was supported by Komolafe et al. (2017), who reported that the economic

Table 3. Perennial trees species composition on selected plots in secondary Forest of Cocoa Research Institute of Nigeria, Ibadan.

S/N	Family	Species composition	Life forms
1	Anacardiaceae (1)	*Anacardium occidentale* L.	Perennial
2	Annonaceae (1)	*Cleistopholis patens* Engl. & Diels	Perennial
3	Apocynaceae (4)	*Alstonia boonei* De Wild.	Perennial
		Funtumia africana (Benth.) Stapf	Perennial
		Plumeria rubra L.	Perennial
		Rauvolfia vomitoria Afzel.	Perennial
4	Arecaceae (1)	*Elaeis guineensis* Jacq.	Perennial
5	Bignoniaceae (1)	*Newbouldia laevis* (P.Beauv.) Seem.	Perennial
6	Bombacaceae (1)	*Ceiba pentandra* (L.) Gaertn.	Perennial
7	Boraginaceae (2)	*Cordia millenii* Baker	Perennial
		Cordia platythyrsa Baker	Perennial
8	Celtidaceae(1)	*Celtis zenkerii* Engl.	Perennial
9	Clusiaceae (1)	*Garcinia kola* Hecke	Perennial
10	Combretaceae (2)	*Terminalia ivorensis* A. Chev.	Perennial
		Terminalia superba Engl. & Diels	Perennial
11	Euphorbiaceae (2)	*Ricinodendron heudelotii* Pierre ex Hecke	Perennial
		Macaranga barteri Mull.Arg	Perennial
12	Fabaceae (13)	*Afzelia africana* Sm. & Pers.	Perennial
		Albizia adianthifolia Schumach.	Perennial
		Albizia coriaria [Welw. ex] Oliv.	Perennial
		Albizia ferruginea (Guill. & Perr.) Benth.	Perennial
		Albizia glaberrima (Schumach. & Thonn.).	Perennial
		Albizia gummifera (J.F.Gmel) C.A.Sm.	Perennial
		Albizia julibrissin Baker	Perennial
		Anthonotha marcrophyla P. Beauv.	Perennial
		Brachyestegia eurycoma Harms.	Perennial
		Senna abbreviata Oliv.	Perennial
		Erythrophleum suaveolens Guill. & Perr.	Perennial
		Gliricidia sepium (Jacq.) Walp.	Perennial
		Millettia thonningii Schumach. & Thonn.	Perennial
13	Irvingiaceae (2)	*Irvingia gabonensis* Baill.	Perennial
		Irvingia grandifolia (Engl.) Engl.	Perennial
14	Lamiaceae (1)	*Tectona grandis* L.f.	Perennial
15	Loganiaceae (1)	*Anthocleista nobilis* G.Don	Perennial
16	Malvaceae (6)	*Bombax buonopozense* P.Beauv.	Perennial
		Cola millenii K.Schum	Perennial
		Pterygota macrocarpa K.Schum.	Perennial
		Sterculia setigera Delile	Perennial
		Theobroma cacao L.	Perennial
		Triplochiton scleroxylon K.Schum.	Perennial

Table 3. Contd.

17	Meliaceae (2)	*Cedrela odorata* L.	Perennial
		Trichilia emetica Vahl	Perennial
18	Mimosaceae (1)	*Albizia zygia* (DC.) J.F.Macbr.	Perennial
19	Moraceae (6)	*Artocarpus heterophyllus* Lam.	Perennial
		Ficus asperifolia Miq.	Perennial
		Ficus capensis Thunb.	Perennial
		Ficus exasperate Vahl	Perennial
		Ficus thonningii Blume	Perennial
		Milicia excelsa (Welw.) C.C.Berg	Perennial
20	Myristicaceae (1)	*Pycnanthus angolensis* Carl L.	Perennial
21	Phyllanthaceae (1)	*Bridelia micrantha* (Hochst.) Baill.	Perennial
22	Rubiaceae (1)	*Morinda lucida benth*	Perennial
23	Rutaceae (2)	*Citrus sinensis* (L.) Osbeck	Perennial
		Zanthoxylum zanthoxyloides Lam.	Perennial
24	Sapindaceae (2)	*Blighia sapida* K. D. Koenig	Perennial
		Lecaniodiscus cupanioides Planch.	Perennial
25	Sapotaceae (1)	*Gambeya albida (G. Don)*	Perennial
26	Solanaceae (1)	*Solanum aethiopicum* L.	Perennial
27	Sterculiaceae (2)	*Cola acuminata* Schott & Endl	Perennial
		Cola gigantea A. Chev.	Perennial
28	Ulmaceae (2)	*Celtis integrifolia* L.	Perennial
		Holoptelea grandis (Hutch.) Mildbr.	Perennial
29	Verbenaceae (1)	*Gmelina arborea* Roxb. ex Sm	Perennial
Total	29	63	63

value of trees may influence its selection for exploitation.

Species diversity indices in wet and dry seasons

The diversity indices revealing the plant community structure at CRIN secondary forest in wet season of 2018 and dry season of 2019 are presented in Table 7. The results obtained revealed that the highest numbers of taxa (87) and individuals (26,304) were obtained among herbaceous species in the wet season. However, trees had similar higher number of species (64) in wet and dry season than shrubs that also had similar number of species (49) in the wet and dry season. However, shrubs had higher number of individuals in wet (3481) and dry (2617) seasons than trees in wet (953) and dry (928) seasons. Dominance values 0.16, 0.03 and 0.03 in the wet season and 0.06, 0.03, and 0.03 in the dry season, respectively for herbaceous, shrubs and trees were low. The low values indicates that there was no predominance of a single species, all species were randomly distributed in the area in both seasons. Simpson index values 0.84, 0.97 and 0.97 in the wet season and 0.94, 0.97, 0.97 in dry season respectively for herbaceous, shrubs and trees were very high, which revealed the richness of species in the area in both seasons. The Shannon index (H’) values were 2.94, 3.56 and 3.81 in the wet season and 3.54, 3.63, and 3.80 in dry season, respectively for herbaceous, shrubs and trees were high and close to the highest value in each life form type. The values obtained indicate that there are many species in both seasons, each with few individuals that are randomly distributed and none was dominant. Equitability index was higher in herbaceous in the dry season (0.83) than wet season

Table 4. Relative Importance Values of Herbaceous Species in Wet and Dry Seasons of CRIN Secondary Forest, Ibadan, Nigeria.

S/N	Species composition	RIV-WS (%)	RIV-DS (%)
1	*Abutilon mauritianum*	0.26	-
2	*Acanthus montanus*	0.16	0.35
3	*Ageratum conyzoides*	1.99	0.27
4	*Andropogon tectorum*	4.14	2.94
5	*Aneilema beniniense*	0.67	-
6	*Aspilia africana*	1.64	5.72
7	*Asystasia gangetica*	1.78	0.99
8	*Axonopus compresus*	0.76	2.31
9	*Bidens pilosa*	0.36	2.31
10	*Blepharis maderaspatensis*	0.98	1.13
11	*Boerhavia coccinea*	0.35	0.5
12	*Boerhavia diffusa*	0.19	0.61
13	*Boerhavia erecta*	0.14	1.69
14	*Brachiaria deflexa*	0.16	0.66
15	*Brachiaria falcifera*	1.47	0.37
16	*Brahiaria lata*	0.11	1.25
17	*Calopogonium mucunoides*	0.36	0.41
18	*Celosia argentea*	0.05	-
19	*Chamaecrista mimosoides*	0.23	0.25
20	*Chromolaena odorata*	25.26	12.49
21	*Cleome rutidosperma*	0.11	1.4
22	*Combretum hispidum*	0.69	0.14
23	*Commelina benghalensis*	1.15	0.39
24	*Commelina erecta*	2.45	1.19
25	*Conysa sumatrensis*	1.31	1.53
26	*Crotalaria retusa*	1.06	3.32
27	*Croton lobatus*	2.20	1.72
28	*Cynodon dactylon*	0.39	1.68
29	*Cyperus amabilis*	3.20	3.63
30	*Cyperus esculentus*	0.43	0.65
31	*Cyperus rotundus*	0.57	4.73
32	*Desmodium scorpiurus*	8.13	0.53
33	*Digitaria exilis*	0.19	-
34	*Digitaria horizontalis*	0.26	-
35	*Eleusine indica*	1.70	-
36	*Emilia coccinea*	1.36	0.94
37	*Eragrostis tremulla*	0.12	-
38	*Euphorbia hirta*	0.19	0.66
39	*Fuirena umbellata*	0.23	0.46
40	*Imperata cylindrica*	2.42	-
41	*Ipomoea aquatica*	1.02	-
42	*Ipomoea triloba*	0.07	-
43	*Laportea aestuans*	0.89	-
43	*Laportea avalifolia*	0.97	-
45	*Mallotus oppositifolius*	0.05	0.6
46	*Mariscus longibracteatus*	0.15	2.06
47	*Melanthera scandens*	0.26	1.69
48	*Mimosa pudica*	0.13	0.37
49	*Momordica charantia*	0.16	0.3
50	*Oldenlandia corymbosa*	0.05	-

Table 4. Contd.

51	*Oplismenus burmannii*	1.15	0.67
52	*Palisota hirsuta*	0.92	1.81
53	*Panicum laxum*	0.19	1.61
54	*Panicum maximum*	1.21	0.85
55	*Paspalum scrobiculatum*	0.03	-
56	*Peperomia pellucida*	0.89	3.25
57	*Perotis indica*	0.49	1.23
58	*Phyllanthus amarus*	0.13	-
59	*Phyllanthus niruri*	0.68	1.31
60	*Pouzolzia guineensis*	0.71	0.33
61	*Pteridium aquilinum*	0.31	-
62	*Pupalia lappacea*	0.53	0.49
63	*Richardia scarbra*	0.29	0.83
64	*Rungia dimorpha*	0.94	0.51
65	*Schrankia leptocarpa*	0.73	0.52
66	*Sclerocarpus africanus*	0.18	0.41
67	*Senna hirsuta*	0.10	1.58
68	*Sesamum alatum*	1.06	1.17
69	*Setaria barbata*	0.79	1.17
70	*Setaria longiseta*	0.34	1.55
71	*Setaria megaphylla*	5.14	1.31
72	*Sida acuta*	0.56	1.53
73	*Sida linifolia*	0.35	0.35
74	*Solanum macrocarpon*	2.34	0.69
75	*Solanum nigrum*	0.34	1.13
76	*Solanum torvum*	0.62	1.33
77	*Solenostemon monostacyus*	0.34	0.62
78	*Spermacoce ocymoides*	0.95	1.03
79	*Spigelia anthelmia*	0.65	0.76
80	*Spurge heterophylla*	0.56	2.02
81	*Synedrella nodiflora*	0.62	2.18
82	*Tacca leontopetaloides*	0.64	0.34
83	*Talinum fructicosum*	0.62	0.39
84	*Tithonia diversifolia*	0.22	0.49
85	*Tridax procumbens*	1.38	3.98
	Total	100.03	100

RIV = Relative Importance Value, WS = Wet Season, DS = Dry Season.

(0.66) and very high in shrubs in the dry season (0.93) and wet season (0.92) and trees in the wet season (0.92) and dry season (0.91). These values indicate that individuals are randomly distributed among all species in each season. There was highest similarity index (100%) between shrubs enumerated in the wet season (WSS) and shrubs enumerated in the dry season (DSS) on one hand and trees enumerated in the wet season (WST) and trees enumerated in dry season trees (DST) on another hand (Table 8). This was followed by the similarity index (76.40%) observed between WSH and DSH while the lowest similarity (1.03%) was observed between WSS and DSS compared to WST and DST. There were no similarity among herbaceous compared to shrubs and trees, respectively in both seasons.

The CRIN forest is an ecosystem with a high diversity of species in distribution and abundance. This was explained by the high Shannon-Wiener values (2.94 - 3.81) obtained for herbs, shrubs and trees in both wet and dry seasons. There were, however, deviations across seasons for the diversity of each of shrubs, herbs and trees. The trees had the highest diversity in the wet season but the shrubs had the highest diversity in the dry season. There was insignificant diversity in both wet and

Table 5. Relative importance values of shrubs species in wet and dry season of CRIN Secondary Forest, Ibadan, Nigeria.

S/N	Species	RIV-WS (%)	RIV-DS (%)
1	*Acacia macrostachya*	2.1	2.7
2	*Agelaea obligua*	4	4.1
3	*Alchornia cordifolia*	0.8	1.0
4	*Angylocalyx oligophyllus*	1.4	1.7
5	*Clerodendron capitatum*	1.3	1.7
6	*Cnestis ferruginea*	3.1	3.9
7	*Coffea canephora*	2.7	2.6
8	*Corynanthe pachyceras*	3.5	3.7
9	*Deinbollia pinnata*	2.2	2.8
10	*Desplatsia subericarpa*	0.6	0.7
11	*Dracaena deisteiliana*	0.1	0.1
12	*Euadenia trifoliata*	1.5	1.9
13	*Euclinia longifolia*	3.7	4.1
14	*Grewia mollis*	0.8	1.0
15	*Hunteria umbellata*	1.7	2.1
16	*Icacinia trichanta*	1.3	1.6
17	*Jatropha curcas*	3.2	2.0
18	*Keetia venosa*	0.5	0.7
19	*Lonchocarpus cyanescens*	4.7	5.8
20	*Lonchocarpus griffonianus*	8.8	7.8
21	*Markhamia tomentosa*	8.5	9.0
22	*Microdesmis puberula*	2.4	2.6
23	*Musa paradisiaca*	3.5	3.1
24	*Pavetta corymbosa*	5.3	2.1
25	*Pleioceras barteri*	0.6	3.0
26	*Psilanthus ebracteolatus*	4.4	0.7
27	*Psychotria fimbriatifolia*	1.3	5.6
28	*Psychotria sciandephora*	6.7	1.7
29	*Rauwolfia vomitoria*	4.3	6.7
30	*Rytiginia umbellata*	3.1	4.8
31	*Solanum erianthum*	7.7	1.3
32	*Solanum torvum*	2.2	5.6
33	*Trichilia prieuriana*	1.3	1.7
		99.3	100.0

RIV = Relative Importance Value, WS = Wet Season, DS = Dry Season.

dry season for herbaceous species. The seasonal similarity in herbs diversity may be attributed to the fallow management in a historically less stressed landscape. This supported the findings that soil conditions, inadequate rainfall pattern and excessive temperature may alter diversity and allows the support of few numbers of herbaceous flora in the forest ecosystem (Thakur, 2018). The forest is diverse with mixed species of herbs, shrubs and trees. This was responsible for the low dominance values in the vegetation structure (herbs, trees and shrubs) of both seasons in the CRIN forest. The seasonal changes did not affect dominance of trees, but shrubs and herbs species dominance increased in the dry season. The few species that can survive the low moisture in the dry season were all well represented. This was also explained by high evenness values obtained for trees, shrubs and herbs in both seasons. The seasonal variation in species diversity of herbs and shrubs agreed with the report of Lu et al. (2010) that suggested high species diversity of herbs with seasonal changes. Also, the increase in diversity of species of herbs and shrubs in the dry season as shown by evenness values may further be attributed to other factors apart from the climate. Moreno and Halffter (2001) and Tuomisto et al. (2003) suggested that landscape pattern and climatic conditions may influence species diversity of an ecosystem. It was

Table 6. Relative importance values of trees species in wet and dry seasons of CRIN Secondary Forest of Ibadan, Nigeria.

S/N	Species	RIV-WS (%)	RIV-DS (%)
1	*Afzelia africana*	0.24	0.24
2	*Albizia adianthifolia*	3.89	0.59
3	*Albizia coriaria*	2.06	1.97
4	*Albizia ferruginea*	0.4	1.1
5	*Albizia glaberrim.*	1.41	0.69
6	*Albizia gummifera*	1.01	0.41
7	*Albizia julibrissin*	2.95	2.85
8	*Albizia zygia*	1.36	1.38
9	*Alstonia boonei*	1.12	1.13
10	*Anacardium occidentale*	0.62	0.64
11	*Anthocleista nobilis*	3.6	3.65
12	*Anthonotha marcrophyla*	1.6	0.58
13	*Artocarpus heterophyllus*	1.23	1.61
14	*Blighia sapida*	0.94	1.25
15	*Bombax buonopozense*	2.63	0.95
16	*Brachyestegia eurycoma*	0.24	0.24
17	*Bridelia micrantha*	0.46	2.66
18	*Cedrela odorata*	1.31	1.32
19	*Ceiba pentandra*	2.19	2.21
20	*Celtis integrifolia*	3.2	3.24
21	*Celtis zenkerii*	3.84	3.89
22	*Citrus sinensis*	0.29	0.3
23	*Cleistopholis patens*	0.7	0.65
24	*Cola acuminata*	1.49	1.51
25	*Cola gigantea*	0.46	0.47
26	*Cola millenii*	2.57	2.6
27	*Cordia millenii*	1.6	1.61
28	*Cordia platythyrsa*	1.36	1.37
29	*Elaeis guineensis*	0.57	0.52
30	*Erythrophleum suaveolens*	0.51	0.96
31	*Ficus asperifolia*	0.96	2.31
32	*Ficus capensis*	2.28	1
33	*Ficus exasperate*	0.99	0.84
34	*Ficus thonningii*	0.83	0.96
35	*Funtumia africana*	0.96	3.95
36	*Gambeya albida*	0.24	0.24
37	*Garcinia kola*	3.13	0.95
38	*Gliricidia sepium*	0.94	1
39	*Gmelina arborea*	1.03	0.97
40	*Holoptelea grandis*	0.99	0.47
41	*Irvingia gabonensis*	0.95	3.07
42	*Irvingia grandifolia*	3.03	3.16
43	*Lecaniodiscus cupanioides*	0.24	0.24
44	*Macaranga barteri*	0.59	1.1
45	*Milicia excelsa*	0.86	0.88
46	*Millettia thonningii*	0.53	0.54
47	*Morinda lucida*	2	1.05
48	*Newbouldia laevis*	1.23	1.97
49	*Plumeria rubra*	0.53	1.25
50	*Pterygota macrocarpa*	3.91	3.97

Table 6. Contd.

51	*Pycnanthus angolensis*	1.12	0.54
52	*Rauvolfia vomitoria*	0.48	1.13
53	*Ricinodendron heudelotii*	1.74	0.48
54	*Senna abbreviata*	1.08	1.78
55	*Solanum aethiopicum*	0.53	0.54
56	*Sterculia setigera*	3.5	3.56
57	*Tectona grandis*	1.88	1.93
58	*Terminalia ivorensis*	0.35	0.35
59	*Terminalia superba*	4.99	5.66
60	*Theobroma cacao*	2.75	2.8
61	*Trichilia emetica*	2.02	2.05
62	*Triplochiton scleroxylon*	5.64	4.96
63	*Zanthoxylum zanthoxyloides*	1.85	1.71
		100	100

RIV = Relative Importance Value, WS = Wet Season, DS = Dry Season.

Table 7. Species diversity indices in wet and dry seasons in CRIN Secondary Forest, Ibadan, Nigeria.

Diversity index	RSH	DSH	RSS	DSS	RST	DST
Taxa_S	86	70	49	49	63	63
Individuals	26304	13490	3481	2617	953	928
Dominance_D	0.16	0.06	0.03	0.03	0.03	0.03
Simpson_1-D	0.84	0.94	0.97	0.97	0.97	0.97
Shannon_H`	2.94	3.54	3.56	3.63	3.81	3.8
Equitability_J	0.66	0.83	0.92	0.93	0.92	0.91

RSH= Field herbaceous in Wet Season, RSS = Field shrubs in Wet Season, RST = Field trees in Wet Season, DSH = Field herbaceous in Dry Season, DSS = Field shrubs in Dry Season, and DST = Field trees in Dry season.

similarly reported that ecological legacies including anthropogenic perturbation especially deforestation, intermediate succession and regeneration potential in the ecosystem of a forest which has not reached is a climax. Though herbs had less number of taxa in the dry season than wet season, the diversity was higher in the dry season than wet season. The implication of this result is that the few species that survived the stress of dry season were all randomly distributed with no particular species dominant. This agreed with the findings of Thakur (2018) that the diversity of herbaceous species in the mixed forest was highest in a study conducted in the dry tropical forest of India. The CRIN forest recorded high species richness (taxa) for herbs, shrubs and trees in both seasons. The species richness of herbs was high in the wet season but for the species richness of shrubs and trees, there was no difference across the season. The openness and closure of forest may influence species richness. The secondary forest may have a closed canopy of trees in the wet season, which may favour the shade loving species (sciophytes), annuals and perennials. However, the open canopy in the dry season may result in the loss of sciophytes and annuals. This was further stressed in the reports of Tang et al. (2010) and Awodoyin et al. (2013) that varying herbaceous species that are shade-loving (sciophytes), annuals and perennial plants are favoured in a closed canopy forest. However, high species diversity of trees indicates a resilience forest with mixed tree species population which may, however, enhance vegetation restoration for the continuous growth of the forest to climax (Tang et al., 2010).

Conclusion

This study revealed a recovering forest from previous degradation due to unsustainable anthropogenic practices. The flora species abundance and composition indicated heterogeneity among trees, herbs and shrubs

Table 8. Similarity between various vegetation types based on their species composition in CRIN secondary forest, Ibadan, Nigeria.

Correlation	WSH	DSH	WSS	DSS	WST	DST
WSH	-					
DSH	76.4	-				
WSS	0	0	-			
DSS	0	0	100	-		
WST	0	0	1.03	1.03	-	
DST	0	0	1.03	1.03	100	-

WSH= Herbaceous in Wet Season, WSS = Shrubs in Wet Season, WST = Trees in Wet Season, DSH = Herbaceous in Dry Season, DSS = Shrubs in Dry Season, and DST = Trees in Dry season.

enumerated. The presence of *C. odorata* in both wet and dry season indicated an ubiquitous herbaceous species which must have been introduced through anthropogenic activities since the plant is a known invasive species in Nigeria. Meanwhile, *T. scleroxylon* and *T. superba* are commonest trees species enumerated in wet and dry season, respectively. These are endemic tree species of importance in Nigeria, suggesting presence of degraded primary forest remnants. The abundance of shrub species however suggested the potential of the forest for resilience. High species diversity and similarity in species across seasons also indicated wide and random distribution of various herbs, shrubs and tree species in the study site. It is recommended that endangered trees endemic to Nigeria such as *T. scleroxylon* and *T. superba* should be adequately protected for sustainable forest resources conservation. Invasive species such as *C. odorata* should be managed in order to prevent homogeneity of the forest landscape. CRIN secondary forest has a potential to improve biodiversity and other ecosystem goods and services due to its resilience potential with its high diversity. Therefore, it should be protected from illegal exploitation of forest resources in order to ensure an *in-situ* conservation of genetic resources present.

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CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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