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Effect of Environmental Factors on the Frequency and Density of Three Functional Groups of Woody Species in Ghana

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Authors' contributions

This work was carried out in collaboration between all authors. Author BB performed the statistical analysis and wrote the manuscript. Author WH designed the study and performed data collection. Authors LP and FB supervised the analysis of the study and the paper work. All authors read and approved the final manuscript.

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ABSTRACT

How plant species are distributed in a given ecosystem is important for ecologists and conservationists because tropical forests are very diverse. This makes the question of what determines species commonness and rarity more interesting. This paper aims to assess the environmental range, frequency and density of three plant functional groups (Pioneer, non-pioneer light demanding and shade tolerant) in Ghanaian tropical forests. We established a 1-ha plot in which trees were inventoried in a nested design, providing a total number of 2205 plots. All living

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trees ≥ 30 cm diameter at breast height (DBH) were sampled in 1ha plot, trees 10–30 cm DBH in 0.1-ha subplots and trees 5–10 cm DBH in 0.05-ha subplots. Then, the following variables were recorded and calculated; frequency (the number of plots in which the species is present) and the average density (the average number of trees per plot, for the plot in which the species is present), and environmental range (rain fall range and soil fertility) of each species. We used a Kruskal-Wallis, Chi-square and multiple regression analysis to evaluate each research question. The results showed that non-pioneer light demanding tree species have wider environmental range and higher frequency than pioneer and shade tolerant tree species. This might be due to non-pioneer light demanding tree species share the characteristics of pioneer and shade tolerant species. Moreover, higher percentages (55%) of non-pioneer light demanding species are commonly found based on the threshold values of three components of rarity (Association among environmental range, frequency and density). In addition, 63% of tree species were rare in seven forms of rarity, and 37% of tree species were commonly found in Ghanaian forest. In conclusion, non-pioneer light demanding tree species have higher frequency and wider environmental range, whereas, shade tolerant tree species have higher density. Overall, environmental factors have effect on the frequency and density of woody species.

Keywords: Commonness; environmental range; rarity; threshold value.

1. INTRODUCTION

Tropical forests are characterized by higher number of tree species and diversity than temperate forests. It is because of the historical cause (higher speciation rates and more stable environment in the tropics), and the better options for maintenance of diversity. Moreover, tropical rain forest represents the most diverse and structurally complex forest in the world [1,2,3]. Besides, tropical forests tend to be tall, dense, and evergreen this leads to low light in the forest floor. Therefore, light (canopy openness) is the most limiting factor for the establishment and growth of tropical rainforest trees [4,5,6]. Variation in forest canopy structure affects both understory light availability and its spatial distribution. As a result, species specialization (pioneers, intermediate and shade tolerant species) could occur with respect to conditions along the temporary environmental gradients between the forest floors. This environmental gradient determines the commonness and rarity of woody species. Therefore, rain forests needs appropriate intervention options and understanding of the reasons that determines the commonness and rarity of woody species. Previous studies stated that rare species are rare in various ways [7,8]. Rabinowitz defined seven forms of rarity. A species can be rare because 1) It has low frequency (it occurs in a few plots) 2) It has a low density (it has a few trees per ha) 3) It has a narrow environmental range. Environmental conditions and resource availability determine species occurrence and their growth and competitive interactions. The distribution of plant species are not controlled by a single physical or biotic factor, but by a complex of factors [9,10].

Environmental variables such as, climatic elements, edaphic factors, light availability, and disturbance affect species distribution, abundance and frequency in the tropics [2,4,11,12,13]. Consequently, plant species were classified into three functional groups: Pioneers (light demanding), non-pioneer light demanding (NPLD) and shade tolerant species [14,15]. These functional groups have their own ability and potential to distribute in the specific area.

Commonness and rarity vary among functional groups. Rarity is broadly used to measure extinction risk for conservation purposes [8,16,17]. Studies in tropical forest indicated that most tree species grow at low densities, i.e. <1 individual/ha for trees with > 10 cm DBH [18].

Pioneer species are thought to occur in a wide range of environmental condition and effective competitors [19] and more frequent and abundant. In contrast shade tolerant species can bear a narrower range of light condition, and perhaps also a narrower range of soil and rainfall conditions. This would result in a lower frequency and abundance. However, information in relation to frequency, density and environmental range of each functional group in the Ghanaian forest is lacking. Therefore, the aim of this study was to understand the frequency, density and environmental range of pioneer, NPLD and shade tolerant species in the tropical forest zone of Ghana to address the following research questions:

1) Do the three functional groups differ in one or more aspects of rarity (frequency, density and environmental range)? Hypothesis: pioneer species have wider environmental range and higher frequency but lower density compared to the other two functional groups.
2) Do functional groups differ in the proportion of species that can be classified as rare? Hypothesis: Pioneer species would be more common in terms of frequency, because they have better capacity to disperse to new areas, and with their opportunistic growth behavior.
3) How are measures of commonness and rarity associated? (Frequency, density and rainfall range)?

Hypothesis: A species that has wider environmental tolerance have higher frequency and higher density.

2. MATERIALS AND METHODS

2.1 Study Site

The study was undertaken in the tropical forests of Ghana, West Africa. The forest in Ghana covers an area of 4,939,958 ha (21.7% of total land mass of Ghana). Annual rainfall ranges from 500 mm to 1750 mm and the mean daily temperature in the forest zone ranges from about 25℃ in the wet season and 27℃ in the dry season. There are seven main forest types. These are: Moist evergreen, Wet evergreen, Deciduous Forest, Coastal Savannah, Transitional Zone, Guinea Savannah, and Sudan Savannah (Fig. 1). Wet evergreen forest is found in the southwest and dry deciduous forest in the northeast. The soils of the forest zone of Ghana have been classified as latosols (cf [20]): old, deeply weathered soils in which rock minerals have been largely altered to kaolin and the sesquioxides of iron and aluminium. Two major types of latosols may be distinguished. Under high rainfall strongly leached type (forest Oxysols) and under low rainfall less strongly leached soil (forest ochrosols) [16].

2.2 Data Sources

A national forest inventory was made between 1986 to1991 by the Forestry Department of Ghana in collaboration of with UK's Overseas Development Administration [14,15]. One hundred twenty-seven forest reserves were systematically sampled using a 2 km * 2 km grid. These reserves cover most of the forest gradient in Ghana from wet evergreen forest in the southwest to dry deciduous forest in the northeast (the two driest forest types not represented as forest reserves in these zones are too small) [13]. At each grid intersection a 1-ha plot was established in which trees were inventorized in a nested design providing a total number of 2205 plots. All living trees ≥ 30 cm diameter at breast height (DBH) were sampled in 1ha plot, trees 10–30 cm DBH in 0.1-ha subplots and trees 5–10 cm DBH in 0.05-ha subplots [14] (Fig. 2). Totally, 258 species were identified and categorized into three functional groups; pioneers (66 species), non-pioneer light demanders (62 species), and shade tolerant (130 species). Pioneers are defined as species that are consistently established and grow in well exposed area. Non-pioneer light-demanding (NPLD) species tend to be shaded at small diameters and illuminated when large, and shade-tolerant species are found as young and old plants in the shade [14,15]. Then after, classification was made for rare species following Rabinowitz classification method. Differentiating common species from rare ones requires setting arbitrary thresholds [7,8,21,22]. Threshold density <1 individual/ha, were considered to be rare for this study [18]. Similarly, we used mean value for frequency (6.15%) and rainfall range (601 mm) as a threshold to differentiate common and rare species.

2.3 Data Analysis

First, we calculated for each species frequency (the number of plots in which the species is present) and the average density (the average number of trees per plot, for the plot in which the species is present) across the study area. To evaluate whether the functional groups differ in their frequency and density, a Kruskal-Wallis test was done using species as data points. Pair-wise differences between functional groups were then tested using Mann-Whitney U tests. We used chi-square (X2) analysis to test whether the observed distribution of each functional group differed from the expected distribution in their frequency, density and environmental range based on the threshold values of three components of rarity. Correlation analyses were done to assess the bivariate relationships between different measures of commonness and rarity (i.e., frequency, density and environmental range). Besides, we did a multiple regression analysis to evaluate to what extent commonness and rarity is driven by the environmental range, to the minimum or maximum environmental conditions a species can tolerate.

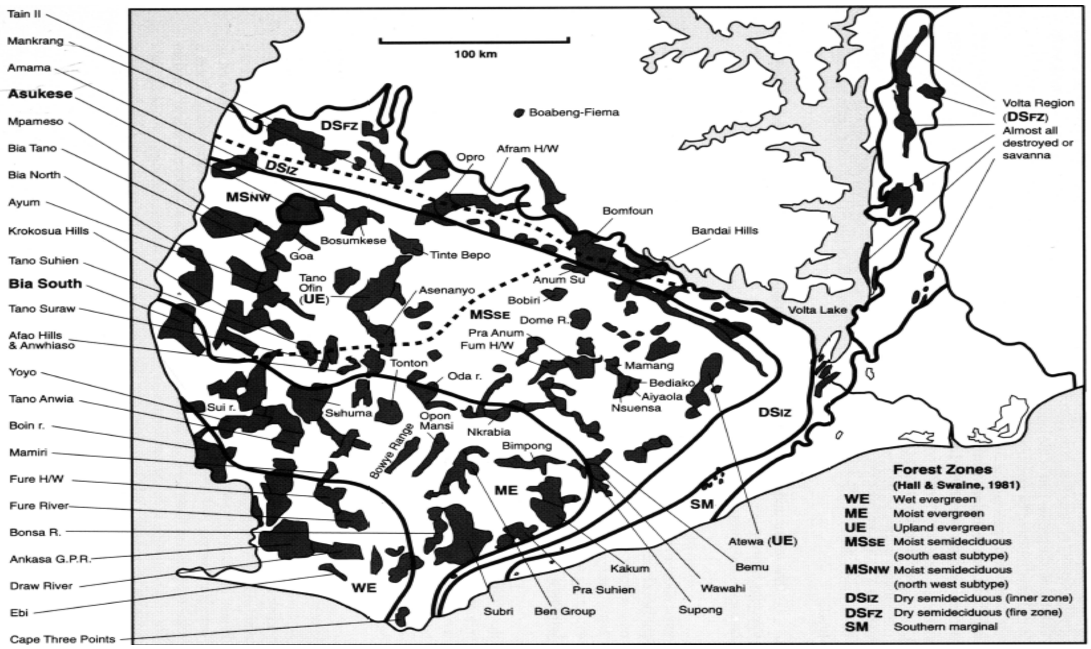

Fig. 1. Forest Reserves in Ghana with selected abbreviated names including those mentioned in the text [14]

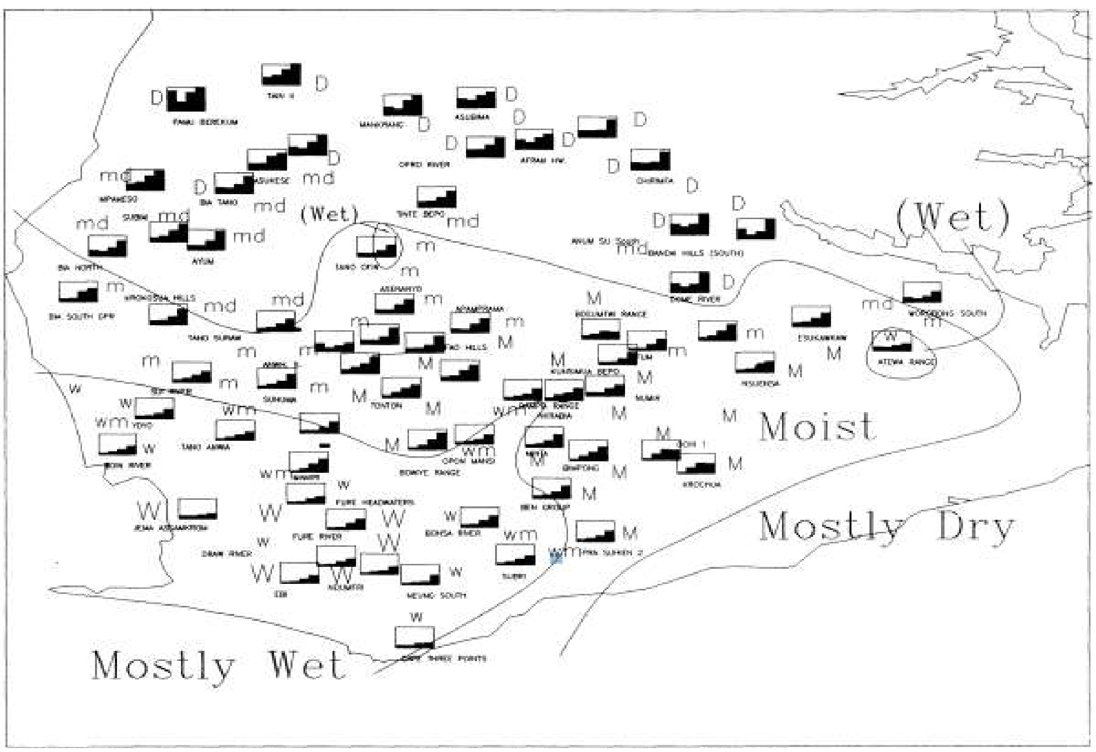

Fig. 2. Showing inventoried reserves (except where too many overlap on the illustration), with an indication of the plot composition as: [14] W: All plots Wet (/evergreen type) of forest w: Wet - Moist, most plots Wet wm: Wet - Moist, most plots Moist M: All plots Moist type of forest m: Moist - Dry, most plots Moist md: Moist - Dry, most plots Dry D: All plots Dry type of forest

3. RESULTS

3.1 Frequency, Density and Environmental Range of Each Functional Group

Frequency, density and environmental ranges differed significantly among the functional groups (Table 2). NPLD species had highest frequency than the other groups. In addition, NPLD species had the largest environmental range (rainfall and soil fertility) followed by pioneer whereas; shade tolerant species had the lowest range. In line with this the proportion of rarity in each functional group was determined. Based on the three components of rarity NPLD species were common in the study area (Table 1).

3.2 Aspects of Rarity among the Functional Groups

The percentage of rare species differed significantly among the functional groups, both when rarity was expressed in terms of frequency (χ^2 test, χ^2 =25.22, DF=2, p<.001), density (χ^2 test, χ^2=9.01, DF=2, p=.01) or environmental range (χ^2 test, $\chi^{2=}$28.71, DF=2, p<.001). Generally, 74% of the pioneer species showed at least one form of rarity, compared to 65% of the shade tolerant species and 45% of the NPLD species (Figs. 3, 4).

3.3 Association between Components of Rarity

All measures of commonness and rarity were significantly and positively related with each other (Table 3). There is a strongly significant positive correlation between density vs. frequency and frequency vs. environmental range (Table 3). When average density was calculated based on all plots, then it was strongly related to frequency but when the average density was calculated based on the plots where the species was present, then it was only moderately related to frequency.

The average density, based on all plots was more determined by the environmental range (soil and rainfall range) than the minimum or maximum of soil fertility and rainfall (Table 3).

The multiple regressions results show that species that are more frequent do also have a higher density (b=0.18, t=13.92, p<.001), and that species with a wider soil and rainfall range do have a higher frequency (soil range; p<.001 and rainfall range; P<.01).

Table 1. The number of tree species recorded in common and rare category depend on the threshold values of the three components of rarity in the study area. The total number of species were 258 (pioneer =66, non-pioneer light demander (NPLD=62 and shade tolerant=130). Threshold density <1 individual/ha [18], frequency ≤6.15% and rain fall range <601 mm were considered as rare species

Functional groups	Density (#/ha)		Frequency (%)		Rainfall range (mm)	
	Rare <1 individual/ha	Common 1≥ individual/ha	Rare ≤6.15%	Common> 6.15%	Narrow (<601 mm)	Wide (≥601 mm)
Pioneer	46	20	36	30	32	34
NPLD	27	35	14	48	13	49
Shade tolerant	76	54	79	51	81	49

Table 2. Differences in frequency, density and environmental range among the three functional groups: pioneer (N=66 species), NPLD (N=62) and shade tolerant (N=130) species. The Kruskal-Wallis test indicates differences among the three groups (p-value). Group means followed by a different letters are significantly different between the functional groups (based on pair-wise Mann-Whitney U tests)

	P-value	Functional groups		
		Pioneer	NPLD	Shade tolerant
Frequency (%)	0.00	13.1 a	22.4 b	10.4 a
Density (#/ ha^{-1}) present plots	0.07	48.2 ab	38.9 a	53.1 b
Rainfall range (mm)	0.00	565.7 b	648.9 c	488.3 a
Soil fertility range (%)	0.00	64.3 b	77.9 c	52.8 a

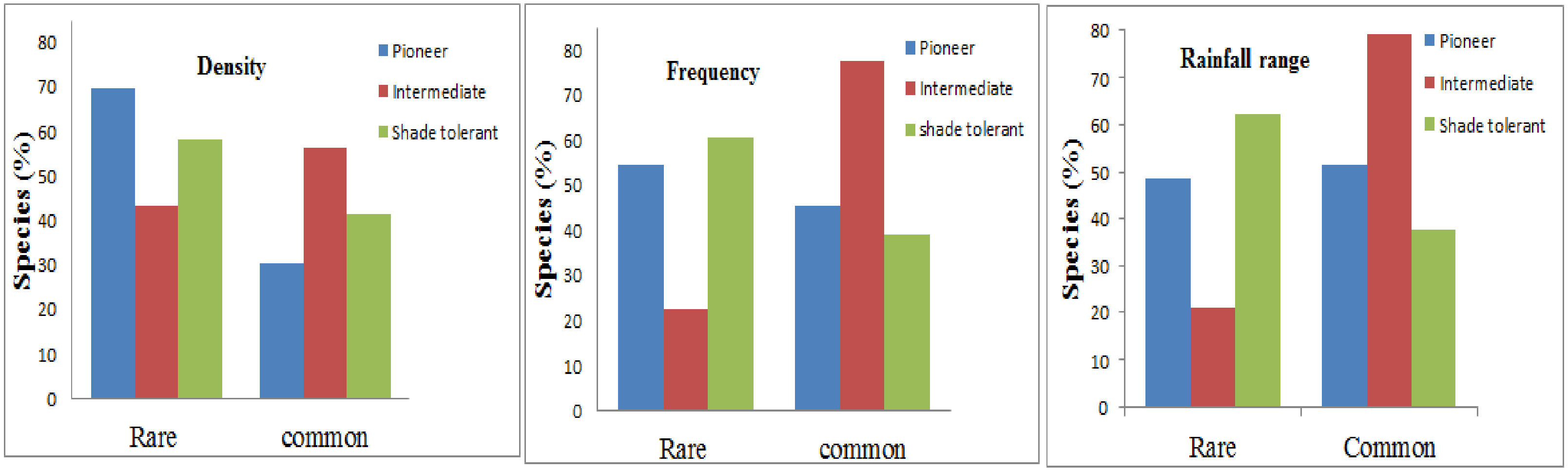

Fig. 3. The percentage of rare and common species of each functional group based on frequency, density and rainfall range. The threshold values for frequency <6.15%, density <1 individual/ha and rainfall range <601 mm were considered to be rare

Table 3. Pairwise correlation between the density, frequency, and environmental niche (minimum, maximum and range in rainfall and soil fertility) of tropical tree species

	Density (all plots)	Density (present plots)	Frequency (%)	Rmin	Rmax	Rrange	Smin	Smax	Srange
Density (all plots)		0.54	0.92	-0.49	0.76	0.76	-0.78	0.73	0.8
Density (present plots)	0.24		0.28	-0.11	0.21	0.18	-0.24	0.18	0.21
Frequency (%)	0.67	0.01		-0.6	0.74	0.85	-0.8	0.84	0.9
R min	-0.18	0.03	-0.35		-0.24	-0.62	0.28	-0.70	-0.63
Rmax	0.32	-0.03	0.47	-0.1		0.87	-0.83	0.53	0.68
Rrange	0.34	-0.04	0.56	-0.67	0.8		-0.77	0.75	0.83
Smin	-0.35	0.06	-0.52	0.22	-0.88	-0.78		-0.58	-0.77
Smax	0.37	-0.02	0.66	-0.71	0.48	0.77	-0.53		0.95
Srange	0.41	-0.04	0.69	-0.6	0.71	0.87	-0.78	0.94	

**All Correlation values are significant at P<.01. (Rmin; rain fall minimum, Rmax; rain fall maximum, Rrange; rainfall range, Smin= Minimum soil fertility; Smax=maximum soil fertility and Srange=soil range)*

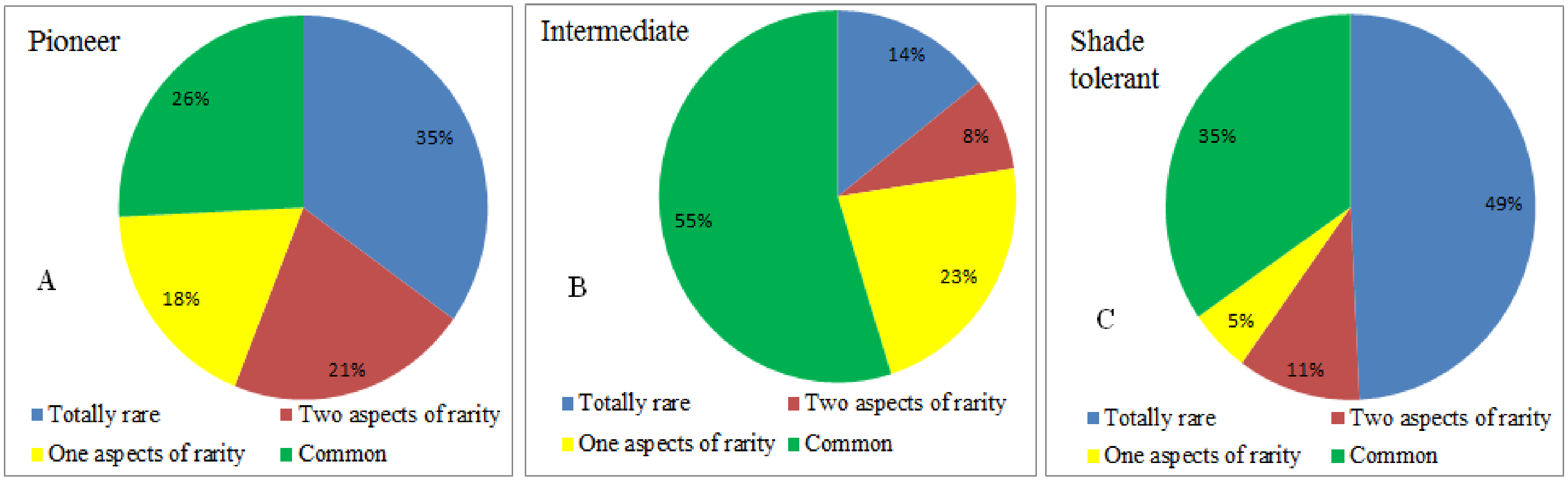

Fig. 4. Relative abundance of tree species in each functional group based on Rabinowitz (1981) species classification (seven forms of rarity and one in common category). Pioneer, intermediate (NPLD) and shade tolerant species respectively, (Common species =high frequency, high density, high rainfall range; totally rare= low frequency, low density and low rainfall; two aspects of rarity is the combination of two low with one high components of rarity, one aspects of rarity is the combination of two high and one low components of rarity)

4. DISCUSSION

In this study we analyzed the distribution of functional groups in their frequency, density and environmental range and how measures of commonness and rarity are associated in the Ghanaian rainforest. In this section, we evaluate the results with respect to the formulated hypotheses and discuss their implications in the context of tropical rainforest dynamics.

4.1 Frequency, Density and Environmental Range of Each Functional Group

Our result revealed that, NPLD species had highest frequency than the other groups. In addition, NPLD species had the widest environmental range (rainfall and soil fertility) followed by pioneer whereas; shade tolerant species had the narrowest range. We hypothesized that pioneer species have wider environmental range and higher frequency but lower density compared to the other two groups. This is because, pioneer species are thought to occur in a wide range of environmental condition [20] and be more frequent than non-pioneers, but because pioneers need gaps for their establishment which are rare in tropical rainforests (on average < 1 gap per hectare is formed annually), they should have a low density. But, it is surprising that, NPLD tree species have wider environmental range and higher frequency than the other groups, in contrary with our hypothesis. Likewise, most tropical tree species have intermediate light requirements [4]. Perhaps this is because NPLD tree species share the characteristics of pioneer and shade tolerant species, and occurs in shade and high light.

Correspondingly, Poorter et al. [23] show for Liberian tree species that species that are shade tolerant or light demanders throughout their life are rare, and that most species have NPLD light requirements and an ontogenetic increase in light requirements over time. Therefore, NPLD tree species may have larger chance for establishment and growth and higher phenotypic plasticity than others.

Density in all plots did not differ among the functional groups, but when average density was calculated based on the plots in which a species is present then shade tolerant tree species had higher density than pioneer and NPLD species. This might be due to the fact that tropical rain forests are dense and closed canopy (shaded environment), which facilitates the establishment of shade tolerant tree species. A Similar result was found in panama rain forest 78% of species were shade tolerant [24].

4.2 Aspects of Rarity among the Functional Groups

We hypothesized that pioneer species would be more common in terms of frequency, because they have better capacity to disperse to new areas, and with their opportunistic growth behavior they can tolerate a wide range of environmental conditions, whereas, shade tolerant species are more common in terms of density, because the shaded conditions in tropical forests are favorable for establishment. In contrast, our findings showed that NPLD tree species are more common than pioneer and shade tolerant species in terms of frequency, density and environmental range. This might be due to NPLD tree species sharing both the characteristics of pioneer and shade tolerant species (Fig. 3). Due to this NPLD species establish and grow both in light exposed and shaded environment.

Overall, 37% of our species were categorized as being super rare (i.e., they had low frequency, and density, and a low environmental range), and 37% were categorized as being super common. Our finding indicates that each functional group differs in one or more forms of rarity. Most of NPLD tree species were commonly found, whereas most of shade tolerant species were extremely rare (Fig. 4). These might be due to NPLD tree species have wider environmental tolerance and very frequent than shade tolerant species. Generally, 37% of the studied species were commonly found and 37% were extremely rare; whereas 26% were fell in one or two aspects of rarity. 63% of tree species fell into seven forms of rarity in this study. On the contrary, [22] concluded that most tropical tree species in the wet Amazon have wider environmental tolerance and are habitat generalist. This might be related with the difference in environmental ranges used for this study and the previous one [22]. Pitman et al. [22] study in a narrow environmental range and also used different definition for habitat specialists compared to our study in which it was carried out in a wider environmental gradient (Ghana). This result suggested that it is difficult to conclude about tropical forest with a specific site study.

4.3 Association between Components of Rarity

Our result showed that a species that has wider environmental tolerance have higher frequency and higher density (Fig. 5). The result confirmed our hypothesis. Aligned to this similar studies confirmed that widespread species have higher frequency and abundance than species with restricted occurrence [25,26,27].

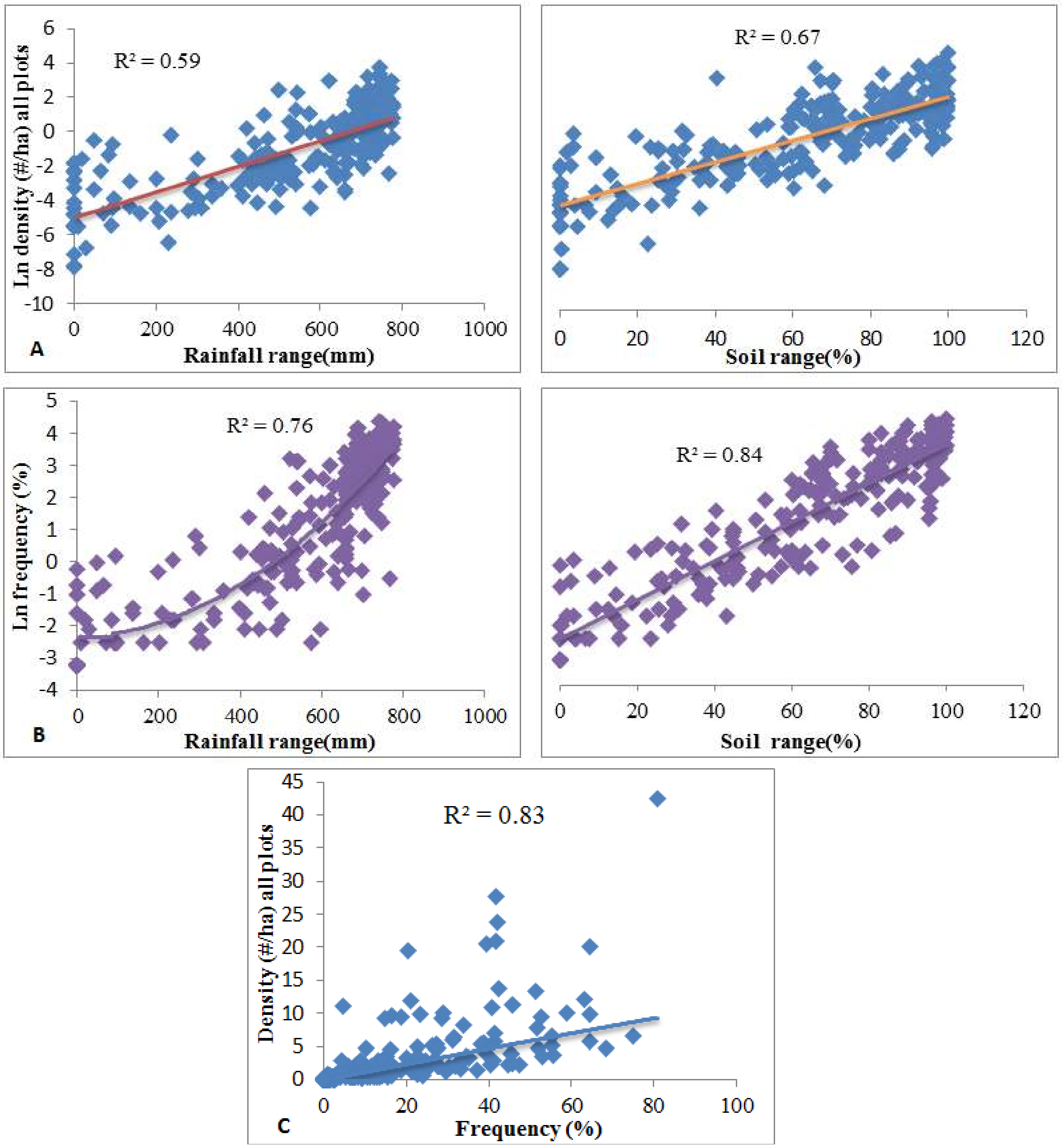

Fig. 5. Scatter plots of the relationship between density and frequency, and the ultimate effect of environmental range (rain fall and soil range) on the density and frequency of 258 Ghanaian tree species; A) The relationship between density and environmental range (rainfall and soil range); B) the relationship between frequency and environmental range (rainfall and soil range); C) The relationship between density and frequency. Regression lines and coefficient of determination (R^2) are shown

Toledo et al. [28] reported that species density was positively correlated with species frequency in the tropical forest. In line with this [29] who show that for western Amazonian tree common trees at local scale have higher frequency and density.

The distribution of plant species is mostly explained by climatic variables and soil conditions [27,29,30,31,32,33,34]. Our findings also indicated that climatic variable and soil condition significantly explain the distribution of tree species in Ghanaian forest. A study by [31] in the north-western Amazon found the same result. On the contrary, [27] and [34] found rainfall was the main driving factor for the distribution of tree species.

5. IMPLICATION FOR CONSERVATION

This study focused on the effect of environmental variables on the frequency and density of functional groups. Our results showed how measures of commonness and rarity associated, and which environmental variable affects the frequency and density tree species. In addition to this, we found which functional group was commonly found and which one was rare. Thus, this study gave information for which species will be requiring conservation (Appendix 1, Table A, B, C). These are 36% of pioneer, 14% of NPLD and 49% of shade tolerant species in the study area (Fig. 4). What can be done to conserve rare species? Maintaining the prevailing rare species in the area is good to maintain the existing forest. In the long run, enrichment planting of the rare species and provide appropriate forest management plan for the forest increases dispersal agents, Ex-situ conservation and germplasm conservation will be required to maintain the forest ecosystem.

6. CONCLUSION AND RECOMMENDATION

The results show that NPLD tree species have higher frequency and wider environmental range, whereas, shade tolerant tree species have higher density. The three components of rarity are strongly positive correlated to each other, thus, a species that has wider environmental range have higher frequency and density in the study area. NPLD tree species are more common based on the threshold values of three components of rarity). Moreover, functional groups are significantly different in one or more forms of rarity. In general, 37% of tree species are extremely rare, 37% of is commonly found; whereas 26% of species fell in one and two aspects of rarity. Overall, environmental factors have an effect on the frequency and density of woody species.

Finally, most of tree species are rare in one or more forms of rarity, therefore, we suggest that strong management incentives to conserve and ensure sustainable management and thereby safeguard for rare species in the Ghanaian rainforest. For example; enrichment planting and maintaining the existing rare tree species or reducing forest disturbance and logging in the area.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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APPENDIX

Appendix 1: List of 258 Ghanaian tree species in different forms of rarity in each functional group.

Table A= Pioneer, Table B= NPLD, and Table C= Shade tolerant

Table A. List of 66 Ghanaian pioneer tree species in three forms of rarity and common category in the study area

Pioneer			
Totally rare species	**Two aspects of rarity**	**One aspects of rarity**	**Common species**
Alchornea cordifolia	*Cussonia bancoensis*	*Nauclea diderrichii*	*Triplochiton scleroxylon*
Allophylus africanus	*Ehretia trachyphylla*	*Terminalia ivorensis*	*Celtis adolfi-friderici*
Antidesma membranaceum	*Holarrhena floribunda*	*Lophira alata*	*Morus mesozygia*
Bersama abyssinica	*Maesopsis emini*	*Holoptelea grandis*	*Petersianthus macrocarpus*
Bridelia atroviridis	*Millettia zechiana*	*Rhodognaphalon brevicuspe*	*Terminalia superba*
Psydrax parviflor	*Pteleopsis hylodendron*	*Bombax buonopozense*	*Alstonia boonei*
Psydrax subcordata	*Rauvolfia vomitoria*	*Elaeis guineensis*	*Baphia pubescens*
Chaetachme aristata	*Shirakiopsis elliptica*	*Erythroxylum mannii*	*Ceiba pentandra*
Clausena anisata	*Tetrorchidium didymostemon*	*Margaritaria discoidea*	*Cleistopholis patens*
Cola digitata	*Vernonia conferta*	*Newbouldia laevis*	*Cola caricifolia*
Cordia senegalensis	*Voacanga Africana*	*Stereospermum acuminatissimum*	*Discoglypremna caloneura*
Croton penduliflorus	*Solanum erianthum*	*Tetrapleura tetraptera*	*Hannoa klaineana*
Cuviera macroura		*Trema orientalis*	*Lannea welwitschii*
Diospyros abyssinica		*Zanthoxylum gilletii*	*Monodora tenuifolia*
Dracaena arborea			*Musanga cecropioides*
Elaeophorbia grandifo			*Ricinodendron heudelotii*
Harungana madagascariensis			*Sterculia tragacantha*
Pouteria alnifolia			
Morinda lucida			
Spathodea campanulata			
Vernonia amygdalina			
Vismia guineensis			
Carica papaya			

Note: (Common species means a species that have highest frequency, highest density, grow in wider rainfall range; totally rare a species that have lowest frequency, lowest density and grow in narrow rainfall range; two aspects of rarity is the combination of two low with one high components of rarity, one aspects of rarity is the combination of two high and one low components of rarity)

Table B. List of 62 Ghanaian NPLD tree species in three forms of rarity and one common category

NPLD			
Totally rare species	**Two aspects of rarity**	**One aspects of rarity**	**Common species**
Pericopsis elata	*Balanites wilsoniana*	*Entandrophragma utile*	*Enthandrophragma angolense*
Albizia glaberrima	*Dialium dinklagei*	*Tieghemella heckelii*	*Enthandrophragma cylindricum*
Anisophyllea meniaudii	*Kigelia africana*	*Lovoa trichilioides*	*Khaya ivorensis*
Anthonotha fragrans	*Majidea fosteri*	*Entandrophragma candollei*	*Heritiera utilis*
Aubrevillea kerstingii	*Okoubaka aubrevillei*	*Mansonia altissima*	*Piptadeniastrum africanum*
Cassipourea gummiflua		*Albizia adianthifolia*	*Antiaris toxicaria*
Hildegardia barteri		*Albizia furruginea*	*Guibourtia ehie*
Placodiscus bancoensis		*Anopyxis klaineana*	*Albizia zygia*
Stemonocoleus micranthus		*Canarium schweinfurthii*	*Distemonanthus benthamianus*
		Antrocaryon micraster	*Pycnanthus angolensis*
		Duboscia viridiflora	*Sterculia rhinopetala*
		Lonchocarpus sericeus	*Amphimas pterocarpoides*
		Ongokea gore	*Bussea occidentalis*
		Ophiobotrys zenkeri	*Chrysophyllum perpulchrum*
			Cola millenii
			Corynanthe pachyeras
			Funtumia africana
			Funtumia elastica
			Homalium tetestui
			Irvingia gabonensis
			Klainedoxa gabonensis
			Duguetia staudtii
			Parinari excels
			Parkia bicolor
			Pentaclethra macrophylla
			Phyllocosmus africanus
			Pterygota macrocarpa
			Sterculia oblonga
			Treculia africana
			Trichilia monadelpha
			Trichilia prieureana
			Trichilia tessmanni
			Trilepisium madagascariense
			Xylia evansii

Table C. List of 130 Ghanaian shade tolerant species in three forms of rarity and one common group

Shade tolerant			
Totally rare species	**Two aspects of rarity**	**One aspects of rarity**	**Common species**
Aeglopsis chevalieri	*Antidesma laciniatum*	*Berlinia confuse*	*Aidia genipiflora*
Afrostyrax lepidophyllus	*Chrysophyllum pruniforme*	*Cylicodiscus gabunensis*	*Annickia polycarpa*
Anonidium manni	*Chrysophyllum subnudum*	*Cynometra ananta*	*Anthonotha macrophylla*
Aporrhiza urophylla	*Coula edulis*	*Diospyros sanza-minika*	*Aulacocalyx jasminiflora*
Aptandra zenkeri	*Diospyros mannii*	*Drypetes pellegrinii*	*Baphia nitida*
Berlinia tomentella	*Discoclaoxylon hexandrum*	*Glyphaea brevis*	*Buchholzia coriacea*
Breviea sericea	*Garcinia kola*	*Scytopetalum tieghemii*	*Calpocalyx brevibracteatus*
Borassus aethiopicum	*Grossera vignei*		*Carapa procera*
Broussonetia papyrifera	*Isolona campanulata*		*Chidlowia sanguinea*
Cassipourea congoensis	*Picralima nitida*		*Cleidion gabonicum*
Cedrela odorata	*Piptostigma fasciculatum*		*Cola chlamydantha*
Chrysophyllum beguei	*Scaphopetalum amoenum*		*Cola nitida*
Citropsis gabunensis	*Strephonema pseudocola*		*Copaifera salikounda*
Crudia gabunensis	*Vitex grandifolia*		*Craterispermum caudatum*
Cynometra megalophylla			*Dacryodes klaineana*
Dasylepis assinensis			*Dialium aubrevillei*
Dasylepis brevipedicellata			*Diospyros kamerunensis*
Dialium guineense			*Drypetes principum*
Dictyandra arborescens			*Greenwayodendron oliveri*
Diospyros canaliculata			*Guarea cedrata*
Diospyros gabunensis			*Guarea thompsonii*
Diospyros heudelotii			*Hexalobus crispiflorus*
Diospyros mespiliformis			*Hymenostegia afzelii*
Diospyros monbuttensis			*Lecaniodiscus cupanioides*
Diospyros soubreana			*Leptaulus daphnoides*
Diospyros viridicans			*Maesobotrya barteri*
Garcinia afzelii			*Mammea africana*
Garcinia epunctata			*Mareya micrantha*
Hymenostegia aubrevillei			*Microdesmis puberula*
Hymenostegia gracilipes			*Millettia rhodantha*
Omphalocarpum pachysteloides			*Monodora myristica*
Lasiodiscus mannii			*Myrianthus arboreus*
Leptonychia pubescens			*Myrianthus libericus*
Lychnodiscus dananensis			*Napoleonaea vogelii*
Lychnodiscus reticulatus			*Nesogordonia papaverifera*
Maerua duchesnei			*Octoknema borealis*
Mallotus oppositifolius			*Panda oleosa*
Manilkara obovata			*Pentadesma butyracea*
Massularia acuminata			*Protomegabaria stapfiana*
Mischogyne elliotiana			*Scottellia klaineana*
Mischogyne elliotiana			*Strombosia glaucescens*
Newtonia aubrevillei			*Synsepalum afzelii*
Newtonia duparquetiana			*Turraeanthus africanus*
Olax subscorpioidea			*Xylopia staudtii*
Oxyanthus pallidus			*Xylopia villosa*

Shade tolerant			
Totally rare species	**Two aspects of rarity**	**One aspects of rarity**	**Common species**
Oxyanthus speciosus			
Oxyanthus unilocularis			
Pausinystalia lane-poolei			
Pellegriniodendron diphyllum			
Piptostigma fugax			
Pycnocoma macrophylla			
Robynsia glabrata			
Smeathmannia pubescens			
Soyauxia grandifolia			
Soyauxia velutina			
Synsepalum aubrevillei			
Talbotiella gentii			
Tapura fischeri			
Tapura ivorensis			
Tectona grandis			
Uvariastrum pierreanum			
Uvariodendron angustifolium			
Uvariodendron occidentale			
Vitex doniana			

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