Effect of some environmental factors on liana abundance in a regenerating secondary lowland rainforest in Nigeria three decades after a ground fire

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Abstract. This study examined variation in liana composition, abundance and environmental variables associated with them in a regenerating secondary rainforest in Ile-Ife, Nigeria. Six sample plots were established in the secondary forest in locations undergoing different degrees of regeneration for this study. All individual lianas were enumerated and girths at breast height were measured. Five soil samples were randomly collected from each sample plot using a soil auger, air-dried and sieved, and were analyzed for pH, particle size distribution, organic carbon, total nitrogen, phosphorus, exchangeable cations and organic matter content. Using Canonical Correspondence Analysis, Correlation and regression analysis, we determined soil variables that influenced the liana abundance in the forest. There were 41 liana species in the forest with *Motandra guineensis* (Apocynaceae) being the most important species. The soil variables affected the liana species differently with the "group IV" liana species showing more preference for all the environmental variables. Liana individuals showed no significant relationship with all the soil variables in the forest. Also, only *Motandra guineensis* showed a strong relationship with all the soil variables in the forest. The study concluded that soil variables affected the liana abundance in the forest differently.

Keywords: association, canonical correspondence analysis, liana, *Motandra guineensis*, soil variables.

1. Introduction

Lianas are one of the most common and important plant life forms in tropical forest ecosystems, and important constituents of the total biodiversity. Their size, situation and relative abundance contribute to the total character of several types of forests (Schnitzer, 2005). They constitute almost 25% of woody stem density (abundance) and species diversity (species richness) in many lowland tropical forests (Appanah et al., 1992). Lianas represent from 25 to 45% of the woody species diversity in tropical forests (DeWalt & Chave, 2004), up to 35% of the total number of woody plant species (Schnitzer et al., 2012) where they can contribute substantially to forest leaf area and biomass (Chave et al., 2001). Lianas typically reach peak abundance in highly seasonal forests ranking second in biomass only to trees (Schnitzer, 2005; DeWalt et al., 2010). There are so-called "liana forests" in French Guiana, Bolivia, Brazil and other tropic regions where lianas dominate over large areas (Perez-Salicrup et al., 2001; Tymen et al., 2016). Several factors have been suggested to influence liana assemblages, but little is known about the environmental factors that associate with liana diversity, composition and community structure in tropical forests. The factors that influence liana abundance in a given habitat include; soil moisture, nutrients (Balfour & Bond, 1993; Nurfazliza et al., 2012), availability of support structures (Muoghalu & Okeesan, 2005; Madeira et al., 2009), altitudinal gradient (Putz & Chai, 1987; Homeier et al., 2010), total amount and seasonality of rainfall (Addo-Fordjour et al., 2013), soil fertility and disturbance (Schnitzer & Bongers, 2002; Schnitzer, 2005), topographic position and natural disturbances (Letcher & Chazdon, 2009). Light availability has also been singled out to be a major driver of liana species proliferation especially in disturbed forests (Laurance et al., 2001) including regenerating forests.

Understanding the causes of increased liana dominance will require a greater understanding of the factors controlling liana community structure. There is some evidence that lianas are increasing in dominance in tropical forests (Wright et al., 2004; Swaine & Grace, 2007). Some authors consider that this pattern could be related to climate change (Malhi & Wright, 2004; van der Heijden et al., 2008) and thus reinforce the need to understand factors that determine liana distribution and abundance.

Efforts to examine the drivers of plant diversity in tropical forests have focused mainly on woody plants in general (Currie et al., 2004) or on trees in particular (ter Steege et al., 2003; Homeier et al., 2010; Yang et al., 2018). The few studies on the effect of environmental factors on the abundance of lianas have been inconclusive in the tropics, with some authors suggesting that environmental factors have no influence on liana abundance while others thought otherwise (e.g. Putz & Chai, 1987; Malizia et al., 2010; Nurfazliza et al., 2012), with only a few studies examining the effect environmental factors on liana abundance in the tropical African formation (e.g. Addo-Fordjour & Rahmad, 2015). Furthermore, information is lacking on factors driv-

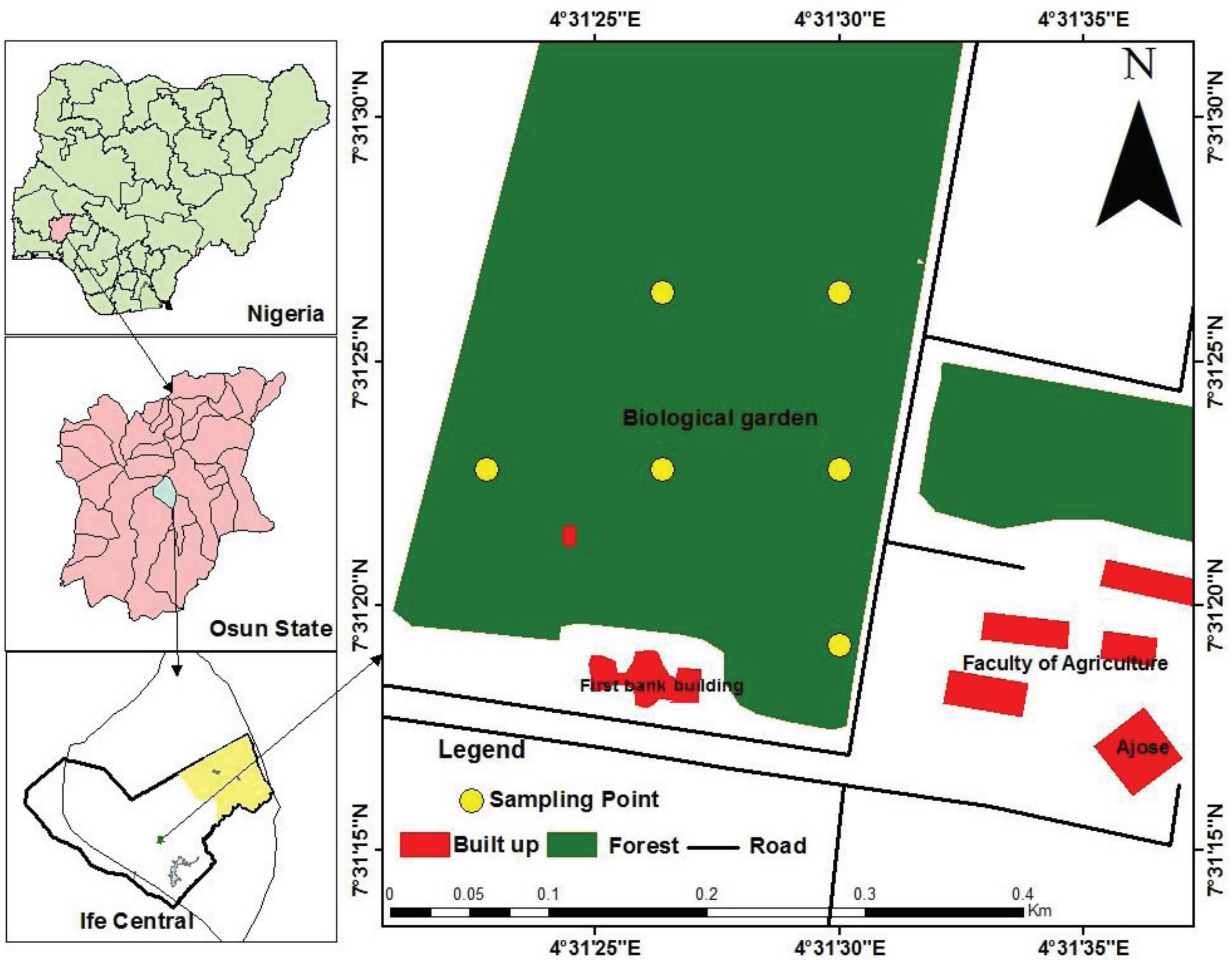

Figure 1. Map of the Biological Gardens of Obafemi Awolowo University, Ile-Ife, with the sampling locations where the study was carried out

ing liana abundance in regenerating secondary forests after a ground fire. The only information on a secondary lowland rainforest regenerating from a ground fire in the African forest formation was conducted by Uwalaka & Muoghalu (2017) where they examined the climber community dynamics after 9 years. Hence, this study investigated the effect of elevation and some soil physicochemical properties on the abundance of lianas in a regenerating secondary rainforest in Nigeria after a ground fire.

The questions addressed in this research were:

What environmental variable(s) determine the abundance and distribution of lianas in a Nigerian rainforest?

What is the association of soil physicochemical properties with liana abundance in a regenerating secondary lowland forest?

2. Study area

The study was carried out within a 205 000 m^2 secondary rain forest in the Biological Gardens of the Obafemi Awolowo University, Ile-Ife, Nigeria which was ravaged by a ground fire in 1983, and was recommended to Protected Area establishing (Uwalaka et al., 2018). Ile-Ife lies between latitude 7° 30′ to 7° 35′ N and longitude 4° 30′ to 4° 35′ E. Six sample plots between latitudes 7° 31.38′ to 7° 31.53′ N and longitudes 4° 31.43′ E to 4° 31.56′ E, were established in the secondary forest in locations undergoing different degrees of regeneration for this study (Muoghalu & Okeesan, 2005; Uwalaka & Muoghalu, 2017). Ile-Ife lies in the lowland rainforest zone (Keay, 1959) and Guineo-Congolian forest drier type (White, 1983). The most frequently occurring liana families in the forest are Apocynaceae, Celastraceae, Euphorbiaceae and Fabaceae (Muoghalu & Okeesan, 2005). There are two prominent seasons in the Ile-Ife area; the rainy season and the dry season. The dry season is short and lasts for 4 months from November to March. The rainy season occurs during the remaining months. Ile-Ife has a mean annual rainfall of 1302 mm per year, relative humidity of 82.8%, average temperature of 25.5° C, solar radiation of 164.30 W / m^2 and average wind speed of 2.06 km / h (Atmospheric Physics Research Group, 2013) (Fig. 1). The area is underlain by rocks of Precambrian age (Wilson, 1922; De Swardt, 1953). The Basement complex of the rock consists of heterogeneous group of rocks which are made up of gneisses, schists, granites and minor rock types such as pegmatites. The soil has been classified as Ultisols (USDA, 1975) with temperature regime that is Isohyperthermic, moisture that is ustic and are made up of clay minerals that are mostly kaolinite. The soils are acidic and have low to medium humus content (Ayodele, 1986).

3. Material and Methods

3.1. Data collection

3.1.1. Sampling procedure and vegetation sampling

Six sample plots (50 m × 50 m each) in the secondary forest in the Biological Gardens were marked out using a measuring tape. In each sample plot, all liana individuals were identified to species level. All individual lianas were enumerated and girths at breast height were measured. Their girths were measured at 1.3 m height or just before the point of branching using diameter tape. Voucher specimens of the species which could not be identified in the field were collected and identified in the IFE Herbarium of the Department of Botany, Obafemi Awolowo University, Ile-Ife, Nigeria. The study was carried out between July 2013 and September 2014. The species richness of the plots was established by listing all the species encountered in each plot.

3.1.2. Soil Sample Collection and Analysis

Five soil samples were randomly collected from each sample plot at a depth of 0-20 cm using a soil auger, each sample was stored in a polythene bag, labelled and taken to the laboratory where they were air-dried and sieved through a 2 mm stainless steel sieve.

The samples were analyzed for pH, particle size distribution, organic carbon, total nitrogen, phosphorus, exchangeable cations (Calcium, Potassium, Magnesium and Sodium) and organic matter content.

Soil organic matter content was determined through the determination of carbon which was determined using elemental analyzer (CHS). The organic matter content was then calculated from the soil carbon content on the assumption that soil organic matter contains 58% carbon. The soil pH was measured in 1:1 soil-water suspension, 1:2 soil : 0.01 M $CaCl_2$, using the glass electrode pH meter (Jenway model 3350). Total nitrogen was determined according to the method of Tel & Rao (1982). Total phosphorus was determined by using the Bray-I solution (Bray & Kurtz, 1945). Exchangeable cations (Calcium, Potassium, Magnesium and Sodium) were determined by leaching soil samples with 1 M ammonium acetate solution and exchangeable sodium and potassium determined on the leachate by flame photometer and calcium and magnesium by Atomic Absorption Spectrophotometer (Alpha Model). Soil particle size distribution was determined by the hydrometer method using hexametaphosphate as the dispersing agent (Buoyoucos, 1951).

Soil pH was determined using freshly collected soil samples.

3.2. Data Analysis

The liana species composition of the plots was established by listing all the species encountered in each plot. The liana species of the forest was compiled from the liana species composition of the plots. The species and family names followed the nomenclature according to PlantList. Importance value index (IVI) was calculated for the liana species in each plot using the following equation (Cottam & Curtis, 1956):

IVI = relative density + relative frequency + relative basal area

The levels of the soil physicochemical properties were compared among the plots using a one way analysis of variance (ANOVA). Fisher's LSD pairwise comparison tests were used in the determination of differences of means among plot pairs in the forest ($p < 0.05$). This analysis was carried out using the SAS version 12 software. The association of the liana communities and the environmental variables (soil physicochemical properties and elevation) was analyzed using the canonical correspondence analysis (CCA) which was performed using the PAST version 3.17 software (Hammer et al., 2001). All species were considered in the entry matrix in order to measure the variable accounting for their presence in the forest. Canonical correspondence analysis was conducted to analyze relationships of the liana abundance with variables (soil physicochemical properties and elevation). There was a total of 15 variables involved in the analysis, namely: elevation, sodium (Na), potassium (K), magnesium (Mg), calcium (Ca), phosphorus (P), nitrogen (N), effective cation exchange capacity (ECEC), total acidity (TA), soil pH, organic carbon (OC), organic matter (OM), and %clay, %silt, %sand contents. The liana species were floristically separated and sorted into four groups based on their densities (group I = liana species with higher densities in plot B or C or in both; group II = liana species with higher densities in only plot D; group III = liana species with higher densities in plot A or F; and group IV = liana species with high densities in almost all study plots). To determine the relationship between individual liana abundance and the various variables, a correlation analysis was carried out between the variables and the liana abundance. The analysis of correlation between the variables and the liana species was carried out, and their strength measured using the Chaddock scale (Hinkle et al., 2003). The strength of the relationship was such that 0.90 to 1.00 (-0.90 to -1.00) represent a very high (positive or negative) correlation, 0.70 to 0.90 (-0.70 to -0.90) represent a high (positive or negative) correlation, 0.50 to 0.70 (-0.50 to -0.70) represent a moderate (positive or negative) correlation, 0.30 to 0.50 (-0.30 to -0.50) represent a low (positive or negative) correlation, while 0.00 to 0.30 (0.00 to -0.30) represent little if any correlation. Furthermore, a preliminary correlation analysis was performed among the variables so as to minimize repetition in terms of expression of the results.

The similarity of the study plots in terms of their species composition was analyzed with the aid of a dendrogram.

4. Results

4.1. Liana species composition in the forest

There was a total of 41 liana species in the forest, distributed into 39 genera and 19 families (Appendix 1). The most common liana species in terms of their occurrence in at least four plots were: *Acacia ataxacantha*, *Baissea campanulata*, *Chasmanthera dependens*, *Combretum* sp., *Jateorhiza micrantha*, *Caesalpinia benthamiana*, *Motandra guineensis*, *Oncinotis gracilis* and *Smilax anceps* (Appendix 1). However, three liana species, that is, *Baissea campanulata*, *Combretum* sp. and *Motandra guineensis*, were found existing in all the plots. The rare liana species in terms of their occurrence in only one plot were: *Abrus precatorius*, *Adenia lobata*, *Friesodielsia gracilis*, *Leptoderris* sp., *Neuropeltis acuminata*, *Oncoba* sp., *Pergularia daemia*, *Philenoptera cyanescens*, *Rytigynia* sp., *Salacia* sp., *Sherbournia bignoniiflora* and *Tacazzea apiculata* (Appendix 1). The most diverse family in the forest were Apocynaceae (9 species) contributing 21.95% of the species in the forest, Fabaceae (7 species) contributing 17.07% of the species in the forest, and Celastraceae (3 species) and Menispermaceae (3 species) both contributing 7.32% of the liana species in the forest (Appendix 1).

The most important liana species in plot A was *Motandra guineensis* (59.16) while the least important liana species were *Abrus precatorius*, *Adenia lobata* and *Triclisia subcordata* (3.55). The most important liana species in plot B was *Motandra guineensis* (83.78) while the least important species was *Friesodielsia gracilis* (0.02). The most important liana species in plot C was *Motandra guineensis* (109.28) while the least important species was *Mondia whitei* (7.28). The most important liana species in plot D was *Motandra guineensis* (69.64) while the *Flabellaria paniculata* (0.14). The most important liana species in plot E was *Motandra guineensis* (103.06) while the least important was *Mezoneuron benthamianum* (16.78). The most important liana species in plot F was *Motandra guineensis* (67.91) while the least important was *Jateorhiza micrantha* (12.00) (Table 1). The five most important liana species in the forest were *Motandra guineensis* (82.14%), *Combretum* sp. (45.95%), *Acacia ataxacantha* (20.39%), *Cissus petiolata* (13.92%) and *Hippocratea* sp. (12.46%) (Appendix 1).

Table 1. Mean and 95% confidence interval values of soil physicochemical properties in a regenerating lowland secondary rainforest, Ile-Ife, Nigeria

Soil variable	Plots					
	I 252 m a.s.l.	II 336 m a.s.l.	III 289 m a.s.l.	IV 277 m a.s.l.	V 316 m a.s.l.	VI 321 m a.s.l.
pH	$7.00^{ab} \pm 2.60$	$7.90^{a} \pm 1.16$	$6.40^{b} \pm 2.18$	$6.58^{ab} \pm 1.40$	$6.56^{b} \pm 2.90$	$7.64^{ab} \pm 3.84$
Ca	$4.06^{bc} \pm 3.28$	$5.33^{ab} \pm 1.40$	$3.59^{c} \pm 2.66$	$4.50^{abc} \pm 2.21$	$4.48^{abc} \pm 2.04$	$5.78^{a} \pm 5.95$
Mg	$1.29^{bc} \pm 1.78$	$2.19^{a} \pm 1.27$	$0.62^{c} \pm 0.67$	$0.99^{c} \pm 1.40$	$1.04^{c} \pm 1.62$	$1.94^{ab} \pm 1.64$
K	$0.15^{b} \pm 0.14$	$0.18^{b} \pm 0.09$	$0.14^{b} \pm 0.06$	$0.16^{b} \pm 0.08$	$0.16^{b} \pm 0.09$	$0.28^{a} \pm 0.31$
Na	$0.22^{a} \pm 0.10$	$0.22^{a} \pm 0.15$	$0.16^{b} \pm 0.10$	$0.17^{ab} \pm 0.09$	$0.20^{ab} \pm 0.09$	$0.20^{ab} \pm 0.15^{ab}$
TA	$0.0017^{a} \pm 0.001$	$0.0013^{a} \pm 0.0003$	$0.0025^{a} \pm 0.0074$	$0.002^{a} \pm 0.0012$	$0.0012^{a} \pm 0.0003$	$0.0017^{a} \pm 0.0016$
ECEC	$5.72^{ab} \pm 5.22$	$7.93^{a} \pm 2.72$	$4.52^{b} \pm 3.41$	$5.83^{ab} \pm 3.67$	$5.89^{ab} \pm 3.67$	$8.21^{a} \pm 7.29$
P	$192.97^{a} \pm 30.89$	$199.18^{a} \pm 41.24$	$194.68^{a} \pm 38.79$	$196.30^{a} \pm 23.94$	$192.57^{a} \pm 43.41$	$194.88^{a} \pm 46.36$
%Sand	$80.20^{a} \pm 22.92$	$76.80^{ab} \pm 15.24$	$76.20^{ab} \pm 12.34$	$76.00^{ab} \pm 14.48$	$70.20^{b} \pm 15.64$	$74.00^{ab} \pm 7.24$
%Clay	$13.60^{ab} \pm 15.46$	$14.80^{ab} \pm 8.50$	$12.60^{b} \pm 8.34$	$16.20^{ab} \pm 11.44$	$19.00^{a} \pm 8.42$	$18.00^{ab} \pm 9.46$
%Silt	$6.20^{b} \pm 8.32$	$8.40^{ab} \pm 7.16$	$11.20^{a} \pm 14.42$	$7.80^{ab} \pm 8.68$	$10.80^{ab} \pm 9.20$	$8.00^{ab} \pm 4.64$
OC	$1.63^{bc} \pm 1.32$	$2.14^{ab} \pm 0.57$	$1.44^{c} \pm 1.07$	$1.81^{abc} \pm 0.88$	$1.80^{abc} \pm 0.83$	$2.33^{a} \pm 2.39$
OM	$2.82^{bc} \pm 2.27$	$3.70^{ab} \pm 0.97$	$2.49^{c} \pm 1.85$	$3.12^{abc} \pm 1.53$	$3.11^{abc} \pm 1.42$	$4.01^{a} \pm 4.12$
N	$0.23^{bc} \pm 0.18$	$0.30^{ab} \pm 0.08$	$0.20^{c} \pm 0.16$	$0.26^{abc} \pm 0.13$	$0.25^{abc} \pm 0.11$	$0.33^{a} \pm 0.34$

Note: Mean values within the same row that have the same superscript are not significantly different ($P < 0.05$).

4.2. Factors affecting liana abundance in the forest

The CCA diagram showed that the different liana species in the forest, which were clustered into four groups were affected by different variables (Fig. 2). For instance, P, silt content and elevation all had more influence on the abundance of the group I species (*Tacazzea apiculata*, *Friesoldielsia gracilis*, *Salacia* sp., *Alafia barteri*, *Aristolochia ringens*, *Leptoderris micrantha*, *Neuropeltis acuminata*, *Pergularia daemia*, *Jateorhiza micrantha* and *Smilax anceps*). This group of species grow more in soil with low concentration of K and clay content. Total acidity had more influence on the group II species (*Cnestis ferruginea*, *Tetracera alnifolia*, *Secamone* sp., *Chlamydocarya* sp., *Sherbournia bignoniiflora*, *Flabellaria paniculata*, *Oncinotis gracilis*, *Grewia carponifolia* and *Oncoba* sp.). This group of liana species increased in abundance with increasing TA, that is, they grow more in acidic soils with lower concentrations of Mg, Na and sand content. The diagram revealed that Na, K and clay content had more influence on the group III species (*Triclisia subcordata*, *Combretum racemosum*, *Mondia whitei*, *Landolphia dulcis*, *Lonchocarpus cyanescens*, *Rytigynia* sp., *Cissus petiolata*, *Chasmanthera dependens*, *Simicratea welwitschii*, *Dalbergia lactea*, *Hippocratea* sp., *Acacia ataxacantha*, *Agalaea obliqua* and an unidentified liana species) while OM, OC, Ca and N had little influence on this group of species. This group of species all thrive more in areas with lower elevation, P, silt content and TA.

Also, in the centre of the triplot diagram, the group IV species (*Combretum* sp., *Baissea campanulata* and *Motandra guineensis*) were influenced by all the variables under study, since they were clustered in the middle of the diagram. The species with high abundance in each group profited more from increasing studied variable characterizing their presence.

4.3. Relationships between liana species and variables

The preliminary correlation analysis among the variables showed that some variables were perfectly correlated. For instance, nitrogen, organic matter, organic carbon and effective cation exchange capacity were highly correlated, with the first three variables showing a 100% size correlation. Some liana species in the forest showed strong (posi-

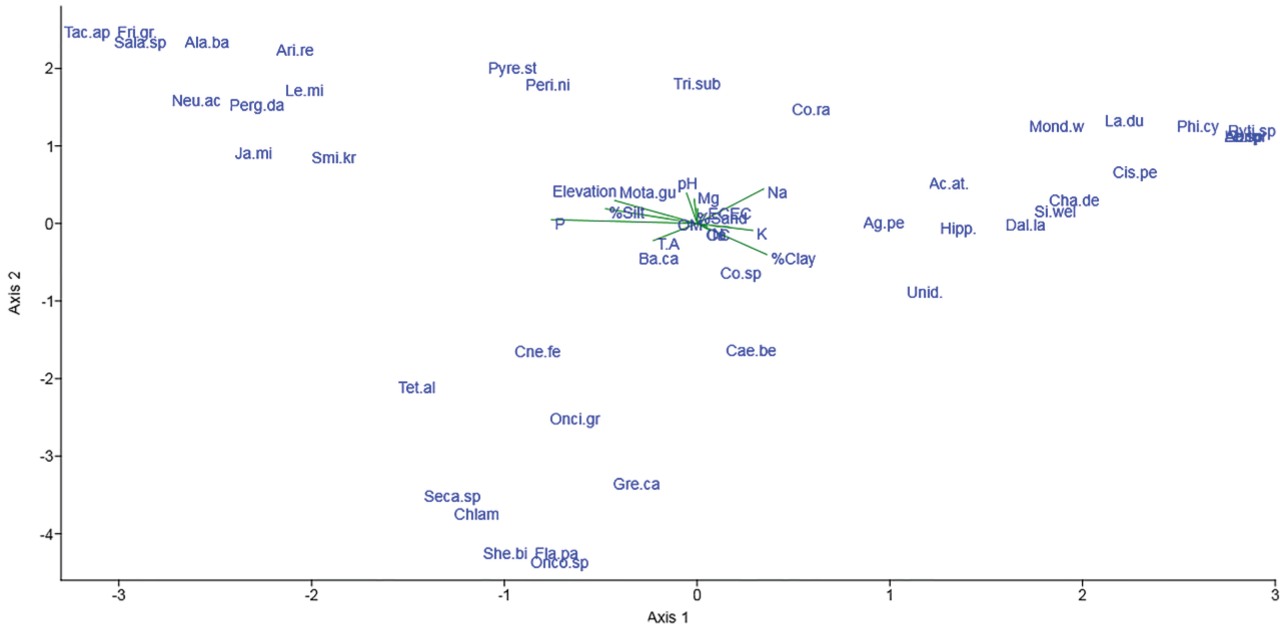

Figure 2. Canonical Correspondence Analysis (CCA) triplot of liana species and soil environmental variables showing the variables controlling the abundance of liana species in a regenerating secondary lowland rainforest, Ile-Ife, Nigeria. Explanations of each abbreviation are presented in Appendix 1

tive and negative) relationships with and similar requirements for some variables. For instance, species in group I showed a high correlation with some variables; *Friesoldielsia gracilis*, *Salacia* sp. and *Tacazzea apiculata* showed similar requirements for phosphorus and showed a high correlation with phosphorus. Also, liana species in group II (for example, *Flabellaria apiculata*, *Oncoba* sp. and *Sherbournia bignoniiflora*) showed similar requirements for the variables. There was a weak relationship between the species in group II and the variables. The liana species in group III (for example, *Neuropeltis acuminata* and *Pergularia daemia*) showed a moderate relationship with all variables except elevation, pH, calcium, magnesium, potassium, phosphorus and sand content. In group IV, only *Motandra guineensis*, which was the most important liana species in the forest, had a very strong relationship with the variables, although the relationships were negative.

Liana individuals in the forest had no significant relationship with any soil variables in the forest (Table 2). The soil variables differed significantly among plots except for the total acidity and phosphorus contents which showed no significant difference in the forest (Table 1). The soil physicochemical properties were highest in plots with higher elevations except the total acidity, sand, clay and silt contents (Table 1).

Table 2. Relationship between liana abundance and soil physicochemical variables in a regenerating secondary lowland rainforest, Ile-Ife, Nigeria

Soil variable	Liana abundance	
	r	*P*
pH	0.229	0.663
Ca (cmol/kg)	-0.211	0.689
Mg (cmol/kg)	0.191	0.717
K (cmol/kg)	-0.335	0.516
Na (cmol/kg)	0.643	0.168
TA	-0.191	0.717
ECEC (cmol/kg)	-0.040	0.940
P (ppm)	-0.074	0.889
Sand (%)	0.783	0.066
Clay (%)	-0.515	0.296
Silt (%)	-0.684	0.134
OC (%)	-0.211	0.689
OM (%)	-0.211	0.689
N (%)	-0.211	0.689

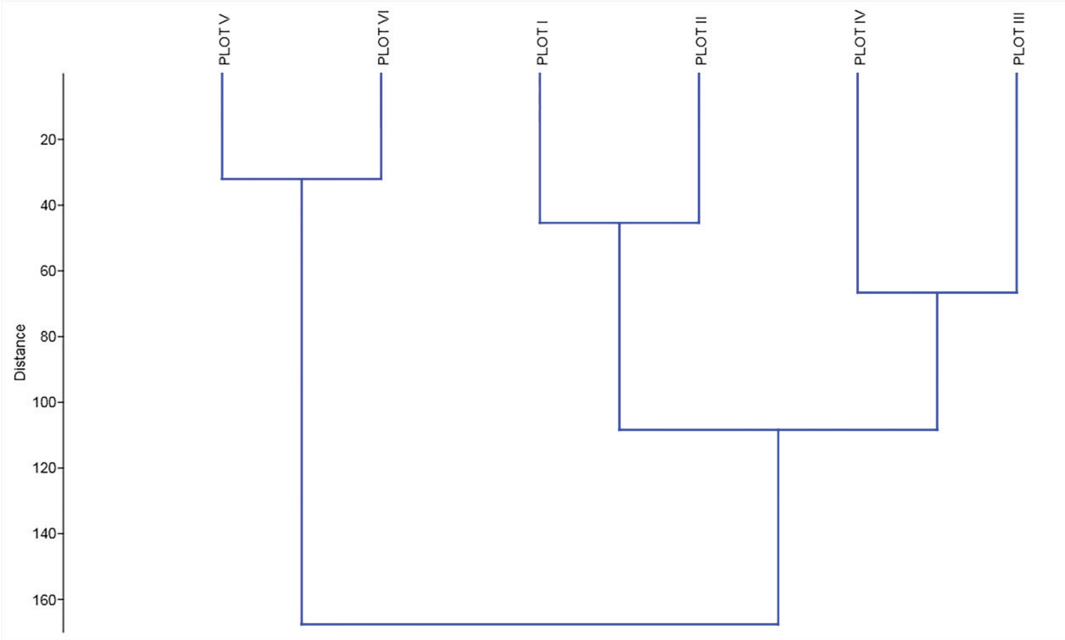

Figure 3. Cluster diagram showing similarity of the study plots in terms of species composition in a regenerating secondary lowland rainforest, Ile-Ife, Nigeria

The cluster analysis showed two cluster associations in terms of species composition among the study plots (Fig. 3). The first cluster showed a similarity between plots E and F. Their species compositions are highly similar; so, all seven climber species of plot E were registered within plot F together with three other climber species. The second cluster showed a similarity among plots A–D due to higher species richness in contrast to two previous areas. This cluster split into two smaller clusters whereby plots A and B, and plots C and D showed similarities in their species composition respectively (Fig. 3). However, species compositions of all six plots are relatively similar to each other. So, there are three taxa recorded in all six plots: *Baessia subsessilis*, *Combretum* sp., *Motandra guineensis*, and also many species which are common for 2-5 plots.

5. Discussion

The secondary forest in which this study was conducted was ravaged by a ground fire about three decades ago and ever since, different ecological vegetation dynamics studies have been conducted, with little consideration given to environmental drivers (most especially soil and elevation) of the composition of some less studied life forms, most especially liana species. This study recognized the importance of some variables in the abundance of some liana species. The six study plots varied in liana species composition, and were influenced differently by the studied variables. The liana species richness recorded in this study was 41 species. This is much lower than the value recorded in some tropical forests in Africa (e.g. Addo-Fordjour & Rahmad, 2015; Ewango et al., 2015) but compares favorably with some findings from outside Africa. For instance, it falls within the range of 3-51 species reported by van der Heijden & Phillips (2009) in a 0.1 ha forest at a lowland tropical moist forest in the neotropics and the range of 12-65 liana species per 0.1 ha plot reported by Nabe-Nielsen (2001) in terra firme in Yasuni, Ecuador. The low number of lianas in the forest could be because the forest is recovering from the ground fire that ravaged it. The existence of single liana stems per species of a single individual could have limited the number of liana species growing in the forest. The most species-rich family in the forest was the Apocynaceae family. This is in line with the findings of many authors in the tropics (e.g. Addo-Fordjour et al., 2009; Yang et al., 2018).

Some liana species in the forest had high importance values (most especially, *Motandra guineensis*) because of their preference for all the studied variables. The negative relationship that existed between this liana species and the studied variables shows that their abundance is not limited by the presence or absence of these variables. The dominance of the single liana species (*Motandra guineensis*) in the forest shows that its abundance increased with the studied environmental variables.

Liana abundance in the forest varied with the studied variables, with some of these variables accounting for the abundance of some group of species in the forest. Specifically, P content, silt and elevation all had influence on the abundance of group I liana species; Mg, Na and sand content had no influence on the abundance of the group II liana species; Na, K and clay content had more influence on the group III species but Ca had no influence; the group IV liana species were influenced by all the variables. This is in line with the findings of Nurfazliza et al. (2012) who reported that liana species abundance in a lowland forest in Negeri Sembilan, Peninsular Malaysia was influenced by different variables. This could be typical of lowland forests. Similar report was made by DeWalt et al. (2006) where different liana species were influenced by different soil physicochemical properties in Sepilok, Sabah. Since some soil physicochemical properties were perfectly correlated with one another in this study (that is, nitrogen, organic carbon and organic matter), they should have similar influence on liana species in the forest, although none of the liana groups showed a strong relationship with any of the variables.

This study also revealed that liana individuals in the forest showed no significant relationship with the studied soil physicochemical variables. This is in contrast with the study of Addo-Fordjour & Rahmad (2015) who reported that soil magnesium and calcium were major determinants of liana species richness and diversity in a tropical forest reserve in Ghana. This could be that liana individuals in the forest are not completely dependent on soil physicochemical variables. It must be noted that soil phosphorus influenced the abundance of some groups of liana species in the forest. This is in line with the findings of Addo-Fordjour & Rahmad (2015) who observed a significant increase in liana abundance with increasing phosphorus concentration in a Ghanaian forest reserve. This is surprising since phosphorus concentration in the forest showed no significant difference among the study plots. This is a further indication that the phosphorus concentration in the forest is more or less uniform in the soil with little or no influence on the liana abundance. It must be noted however that the trend with which the association of the liana abundance and soil variables followed in the forest may be just as Malizia et al. (2010) stated that liana composition affects rather than respond to some environmental variables. Therefore, it cannot be fully stated that specific soil variables condition the availability of liana species in a secondary forest after a ground fire. This is in line with the assertion of Jhariya (2014) who noted that forest fire has a means of influencing soil nutrient dynamics as well as organic carbon availability.

This study has shown that liana abundance differed with different variables with only a group of liana species (group IV) with high importance values increasing with increasing variables. However, although the studied variables influenced liana abundance, it is rather unclear as to which unique variable(s) is/are responsible for the abundance of liana species in the secondary forest. This could be a unique trend in lowland rainforests. Therefore, future studies on more properties apart from the ones used in this study are needed to ascertain the unique factors influencing liana species abundance in the forest.

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Appendix 1. Species Composition and Importance Value Index of Liana Species in a Lowland Secondary Rain Forest in Ile-Ife, Nigeria

Abbreviation	Name	Plot A				Plot B				Plot C				Plot D				Plot E				Plot F			
		RD	RF	RDo	IVI	RD	RF	RDo	IVI	RD	RF	RDo	IVI	RD	RF	RDo	IVI	RD	RF	RDo	IVI	RD	RF	RDo	IVI
	Annonaceae																								
Fri.gr.	*Friesodielsia gracilis*	-	-	-	-	-	-	0.02	0.02	-	-	-	-	0.53	5	-	5.53	-	-	-	-	-	-	-	-
	Apocynaceae																								
Ala.ba	*Alafia barteri*	0.32	3.45	0.31	4.07	5.31	3.70	4.08	13.09	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ba.ca	*Baissea campanulata*	1.26	3.45	0	4.71	4.03	3.70	0	7.74	4.91	6.67	0.087	11.66	5.32	5	0.04	10.36	5.30	14.29	0.16	19.75	9.52	10	0.50	20.02
La.du	*Landolphia dulcis*	0.84	3.45	2.07	6.36	0.21	3.70	0.65	4.56	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mond.w	*Mondia whitei*	1.68	3.45	0.08	5.21	-	-	-	-	0.61	6.67	-	7.28	-	-	-	-	-	-	-	-	-	-	-	-
Mota.gu	*Motandra guineensis*	32.88	3.45	22.83	59.16	39.92	3.70	40.17	83.78	46.62	6.67	55.99	109.28	27.66	5	36.99	69.64	55.30	14.29	33.47	103.06	34.29	10	23.63	67.91
Onci.gr	*Oncinotis gracilis*	1.37	3.45	1.78	6.59	1.27	3.70	2.03	7.01	2.45	6.67	3.28	12.40	10.11	5	11.03	26.14	-	-	-	-	-	-	-	-
Perg.da	*Pergularia daemia*	-	-	-	-	-	-	-	-	1.23	6.67	0.04	7.94	-	-	-	-	-	-	-	-	-	-	-	-
Seca.sp	*Secamone* sp.	-	-	-	-	0.21	3.70	0.04	3.96	-	-	-	-	1.06	5	0.03	6.09	-	-	-	-	-	-	-	-
Tac.ap	*Tacazzea apiculata*	-	-	-	-	0.21	3.70	0.02	3.94	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Aristolochiaceae																								
Ari.re	*Aristolochia repens*	0.11	3.45	0.01	3.56	1.27	3.70	0.74	5.71	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Celastraceae																								
Hipp.	*Hippocratea* sp.	0.21	3.45	0.49	4.14	-	-	-	-	-	-	-	-	-	-	-	-	5.30	14.29	19.67	39.26	7.62	10	13.75	31.37
Sala.sp	*Salacia* sp.	-	-	-	-	0.21	3.70	-	3.92	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Si.wel	*Simicratea welwitschii*	5.15	3.45	3.02	11.62	-	-	-	-	0.61	6.67	0.11	7.39	1.60	5	0.56	7.16	-	-	-	-	-	-	-	-
	Combretaceae																								
Co.ra	*Combretum racemosum*	1.89	3.45	2.17	7.51	1.06	3.70	0.51	5.28	1.23	6.67	3.67	11.56	-	-	-	-	-	-	-	-	-	-	-	-
Co.sp	*Combretum* sp.	14.18	3.45	12.38	30.01	12.31	3.70	18.49	34.51	13.50	6.67	5.10	25.26	25.53	5	37.63	68.17	22.73	14.29	24.49	61.51	25.71	10	20.52	56.23
	Connaraceae																								
Ag.pe	*Agalaea pentagyna*	-	-	-	-	0.21	3.70	0.25	4.16	-	-	-	-	-	-	-	-	-	-	-	-	2.86	10	0.47	13.33
Cne.fe	*Cnestis ferruginea*	0.21	3.45	0.06	3.72	0.85	3.70	0.78	5.33	-	-	-	-	1.06	5	0.86	6.92	-	-	-	-	-	-	-	-
	Convolvulaceae																								
Neu.ac	*Neuropeltis acuminata*	-	-	-	-	-	-	-	-	1.84	6.67	9.74	18.25	-	-	-	-	-	-	-	-	-	-	-	-
	Dilleniaceae																								
Tet.al	*Tetracera alnifolia*	-	-	-	-	0.85	3.70	-	4.55	-	-	-	-	1.06	5	-	6.06	-	-	-	-	-	-	-	-
	Icacinaceae																								
Chlam	*Chlamydocarya* sp.	-	-	-	-	-	-	-	-	0.61	6.67	0.35	7.63	4.26	5	0.18	9.44	-	-	-	-	-	-	-	-
Pyre.st	*Pyrenacantha staudtii*	0.21	3.45	-	3.66	0.85	3.70	-	4.55	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Abbreviation	Name	Plot A				Plot B				Plot C				Plot D				Plot E				Plot F			
		RD	RF	RDo	IVI	RD	RF	RDo	IVI	RD	RF	RDo	IVI	RD	RF	RDo	IVI	RD	RF	RDo	IVI	RD	RF	RDo	IVI
	Leguminosae																								
Abr.pr	*Abrus precatorius*	0.11	3.45	-	3.55	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ac.at	*Acacia ataxacantha*	7.46	3.45	27.78	38.69	0.85	3.70	8.99	13.54	3.07	6.67	9.18	18.91	1.60	5	0.80	7.40	-	-	-	-	4.76	10	29.05	43.81
Cae.be	*Caesalpinia benthamiana*	2.10	3.45	3.21	8.76	1.91	3.70	5.17	10.79	-	-	-	-	5.85	5	4.06	14.91	1.52	14.29	0.98	16.78	2.86	10	1.87	14.72
Dal.la	*Dalbergia lactea*	1.37	3.45	0.51	5.32	0.21	3.70	-	3.92	-	-	-	-	0.53	5	0.24	5.77	-	-	-	-	-	-	-	-
Le.mi	Leptoderris micrantha	0.11	3.45	0.03	3.58	0.64	3.70	0.16	4.50	1.23	6.67	0.13	8.03	-	-	-	-	-	-	-	-	-	-	-	-
Le.sp	*Leptoderris* sp.	0.32	3.45	0.04	3.80	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Phi.cy	*Philenoptera cyanescens*	0.53	3.45	0.49	4.46	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Malphighiaceae																								
Fla.pa	*Flabellaria paniculata*	-	-	-	-	0.64	3.70	-	4.34	-	-	-	-	-	-	0.14	0.14	-	-	-	-	-	-	-	-
	Malvaceae																								
Gre.ca	*Grewia carpinifolia*	0.42	3.45	0.61	4.48	0.21	3.70	2.30	6.21	-	-	-	-	3.19	5	5.09	13.28	-	-	-	-	-	-	-	-
	Menispermaceae																								
Cha.de	*Chasmanthera dependens*	14.50	3.45	2.34	20.29	1.06	3.70	0.18	4.94	-	-	-	-	3.19	5	0.69	8.88	6.82	14.29	2.09	23.20	3.81	10	0.42	14.23
Ja.mi	*Jateorhiza micrantha*	-	-	-	-	11.04	3.70	3.68	18.42	7.98	6.67	2.19	16.83	2.66	5	0.18	7.84	-	-	-	-	1.90	10	0.10	12.00
Tri.sub	*Triclisia subcordata*	0.11	3.45	-	3.55	0.21	3.70	-	3.92	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Passifloraceae																								
Ad.lo	Adenia lobata	0.11	3.45	-	3.55	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Periplocaceae																								
Peri.ni	*Periploca nigrescens*	3.68	3.45	7.54	14.66	9.13	3.70	10.62	23.45	3.68	6.67	8.72	19.07	-	-	-	-	-	-	-	-	-	-	-	-
	Rubiaceae																								
Ryti.sp	*Rytigynia* sp.	0.11	3.45	0.21	3.77	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
She.bi	*Sherbournia bignoniiflora*	-	-	-	-	-	-	-	-	-	-	-	-	0.53	5	-	5.53	-	-	-	-	-	-	-	-
	Salicaceae																								
Onco.sp	*Oncoba* sp.	-	-	-	-	-	-	-	-	-	-	-	-	1.06	5	0.83	6.90	-	-	-	-	-	-	-	-
	Smilacaceae																								
Smi.kr	*Smilax anceps*	0.74	3.45	0.08	4.26	5.10	3.70	0.58	9.38	10.43	6.67	1.43	18.53	2.13	5	0.08	7.21	-	-	-	-	-	-	-	-
	Vitaceae																								
Cis.pe	*Cissus petiolata*	6.83	3.45	10.41	20.68	-	-	-	-	-	-	-	-	-	-	-	-	3.03	14.29	19.13	36.45	6.67	10	9.70	26.37

Keys: RD = Relative Density; RF = Relative Frequency; RDo = Relative Dominance; IVI = Importance Value Index