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Vegetation and soil status on an 80 year old lava flow of Mt. Cameroon, West Africa

Vegetación y estado de los suelos en un flujo de lava de 80 años en Mt. Camerún, Oeste de África.

Fonge B. A.1*; Yinda G.S.1; Focho D.A.2;Fongod A.G.N.1 Bussmann R.W.3

1University of Buea, P.O. Box 63 Buea, Southwest
Province, Cameron, Email: bambofonge@yahoo.com,
*Author for correspondence, yinda_sendze@hotmail.com,
tina_fongod@yahoo.com
2University of Dschang, P.O Box 217 Dschang, Cameroon,
Email: dafocho@yahoo.fr
3University of Hawaii, Harold L. Lyon Arboretum, 3860
Manoa Rd. Honolulu, HI 96822, USA. Email: bussmann@hawaii.edu

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Abstract

Vegetation surveys were carried out in 2001-2002 on the 1922 lava flow on Mount Cameroon in order to assess species richness and soil status. A total of 102 species were recorded belonging to 47 families, including 21 tree species belonging to 13 families, 13 shrubs belonging to seven families, 20 herb species belonging to 10 families, seven climbers belonging to five families, 17 ferns belonging to eight families, five moss species, four lichen species, 13 orchids species and two fungi species. The family Orchidaceae was the most represented herb family while Rubiaceae was the most represented tree family. A total of 106 trees with dbh from 1 - 10 cm were recorded, with mean dbh of 6.65 cm and mean total BA of 1885.3 cm2 recorded. *Syzygium guineense* had the highest BA (769.68 cm2), with highest relative density (16.807%), relative dominance (40.83%) and CVI (57.638%) with an Important Value Index = 68.24%). *Alchornea cordifolia* with BA = 537.21cm2 had a relative density = 15.966%, relative dominance = 28.495%, CVI = 44.462%, and IVI of 55.57. *Mangifera indica* had the least with BA = 0.785 cm2, relative density = 0.821, Relative dominance = 0.042, CVI = 0.882 and IVI = 2.84%. *Chromolaena odorata, Nephrolepis pumicicola, Nephrolepis biserrata* were frequent with *Nephrolepis pumicicola* having the highest density (3.35%) and 13.87% relative density. *Alstonia boonei and Maytenus* sp. had the lowest densities. Shannon-weaver diversity (H1) and Simpson diversity indices are 3.58 and 22.863 respectively. The physico-chemical parameters of the soil from the edges and the centre of the lava were analysed. Colour ranged from very dark grey (5y 3/1), in the centre, to dark reddish brown (5y 3/3, 5y 3/4). The topsoil was mostly made up of organic matter. The soils were acidic (pH from 4.62 - 5.31), soil sand content was highest at the right edges (56.5%) and lowest at the centre (16.8%). Total Nitrogen was found to be highest on the lava centre, (3.53%), and lowest at the right edge (1.65%) while the total phosphorus was highest at the left edge (27.15) and lower (19.3) on the centre; being relatively higher than all other soils in Cameroon (12 - 16%), Calcium (Ca) is relatively high in the complex and shows the highest percentages among all cations. The principal component analysis showed that PC1 (69.3%) is most strongly affected by total Nitrogen, exchangeable cations, CEC, organic carbon and organic matter, while PC2 (30.70%) is strongly associated with total phosphorus (Bray II) and sand silt content. These are the main factors that influence vegetation growth on this lava.

Resumen

La vegetación en el flujo de lava de 1922 del Mt. Camerún, fue estudiado entre 2001-2002 para investigar la riqueza de especies y el estado de suelo. Se encontraron 102 especies de plantas de 47 familias, incluyendo 21 especies de árboles en 13 familias, 13 arbustos pertenecientes a siete familias, 20 hierbas en 10 familias, siete trepadoras en cinco familias, 17 helechos en ocho familias, cinco briofitos, cuatro líquenes, 13 especies de orquídeas y dos en hongos. Las orquídeas representan la familia más importante de hierbas, mientras que las Rubiaceas son la familia más rica de árboles. Se encontró un total de 106 árboles con dap de 1-10 cm., y un dap medio de 6.65 cm., y un total de área basal (AB) de 1885.3 cm2. *Syzygium guineense* tuvo la AB más alta (769.68 cm2), la densidad relativa más alta (16.807%), dominancia relativa (40.83%) y CVI (57.638%) con índice de valor de importancia (IVA) = 68.24%. *Alchornea cordifolia* con BA = 537.21cm2 , densidad relativa de = 15.966%, dominancia relativa = 28.495%, CVI = 44.462%, y IVA de 55.57. *Mangifera indica* tuvo la AB mas pequeña con 0.785 cm2, densidad relativa = 0.821, dominancia relativa = 0.042, CVI = 0.882 y IVA = 2.84%. *Chromolaena odorata, Nephrolepis pumicicola, Nephrolepis biserrata* estuvieron frecuente con *Nephrolepis pumicicola* con la densidad más alta (3.35%) y 13.87% densidad relativa. *Alstonia boonei* y *Maytenus sp.* Tuvieron la densidad mas baja. Los índices de Shannon-weaver (H1) y Simpson fueron 3.58 y 22.863. Los parámetros físico-químicos de los suelos de los límites y del centro del flujo de lava fueron analizados. El color estuvo entre (5 y 3/1) en el centro hasta (5 y 3/3, 5 y 3/4). El primer horizonte del suelo consistió de materia orgánica. Los suelos se muestran ácidos (pH de 4.62 - 5.31), y el contenido de arena estuvo mas alto en los limites (56.5%) y mas bajo en el centro (16.8%). El Nitrógeno total estuvo mas alto en el centro (3.53%), y mas bajo en el lado derecho (1.65%) mientras que el fósforo estuvo mas alto en el lado izquierdo (27.15%) y mas bajo

(19.3%), una cantidad mas alta que en suelos normales de Camerún (12 - 16%).

Introduction

Mt Cameroon is located in the Gulf of Guinea at the South West Province of Cameroon. Its longest axis, as shown in **[[Figure1]]**, about 45 km long and 30 km wide runs SW to NE between latitudes 3°57' to 4°27'N and longitudes 8°58' to 9°24'E, with the main peak at 4°7'N and 9°10'E (Tchouto, 1996; Suh *et al*., 2003). It is considered to be one of the most active volcanoes in Africa, having erupted eight times within the past 100 years (1909, 1922, 1925, 1954, 1959, 1982, 1999 and 2000). Soils on Mt Cameroon are mostly of recent age and derived from active volcanic rocks. They are generally fertile but have a poor moisture retaining capacity (Cheek, 1992). The soil temperature, measured at depths of 10 cm, varies from 25°C (at 200 m) through 20°C (at 1100 m) to 15°C at 2200 m above sea level (Payton, 1993). The region has two main seasons: a wet season with heavy rains from June to October and a dry season from November to May. The mean annual rainfall of this area varies between 2085 mm, near Ekona on the leeward side, to 9086 mm at Debundscha on the windward side of the mountain. This is the wettest place in Africa (Fraser *et al*., 1999). Mean monthly temperatures, at sea level, vary from 19°C to a maximum at 30°C during the months of March and April (Fraser *et al*., 1998). The humidity range is between 75% and 80% throughout the year on the southwestern side of the mountain. The persistent cloud cover and mist make Mt Cameroon one of the areas, receiving the lowest annual sunshine in West Africa. Sunshine ranges from 900 to 1200 hours/year at sea level and decreases with altitude (Payton, 1993). Plant recovery on the different lava flows has resulted in a rich and mosaic type of vegetation on the mountain slopes. There have been a number of publications on the geology of the mountain and most of the eruptions of the twentieth century (Deruelle *et al*., 1987; Fitton *et al*., 1983; Géze, 1943; 1953; Suh *et al*., 2001; 2003). Very few studies have been concerned with reporting plant recolonisation of Mt Cameroon (Keay, 1959; Benl, 1976; Fraser *et al*., 1998; Ndam *et al*.; 2002). No studies so far have attempted to establish any relationship between the plant diversity and the soil nutrient status of any of the lava flows.

The present study thus aims at updating plant inventories on the 1922 lava flow and reporting on the present nutrient status of the soil 80 years after the eruption.

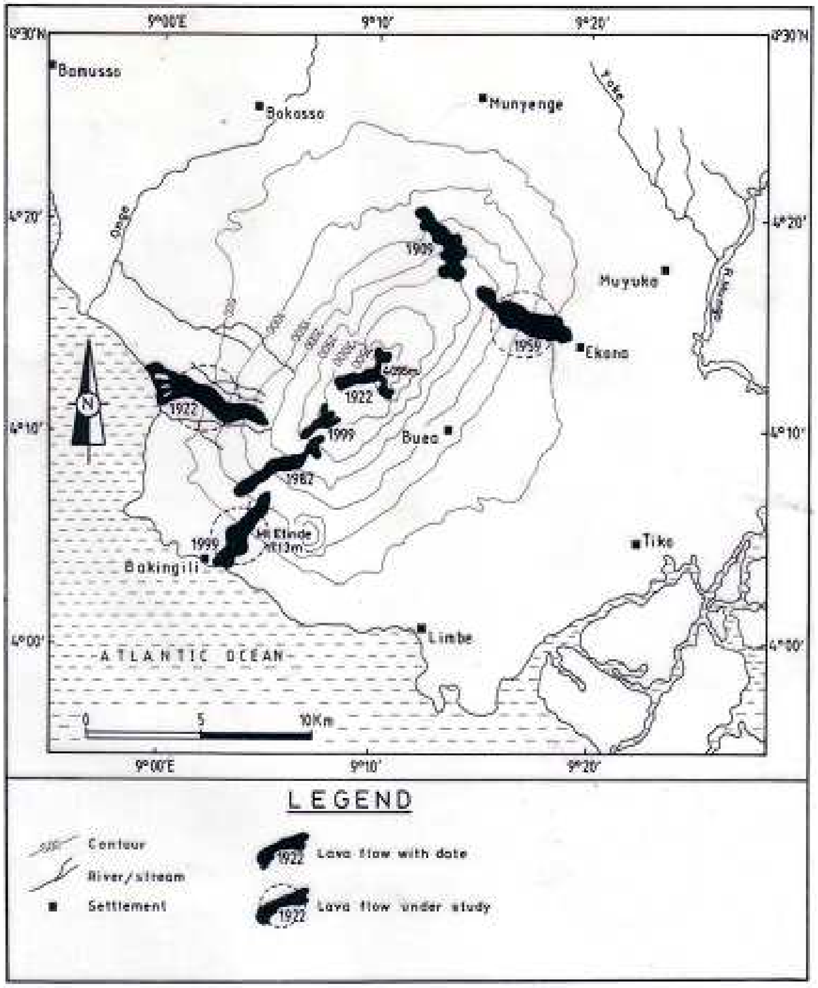

Fig. 1: Map showing the different lava sites on Mt. Cameroon

Materials and Methods

Study Sites

The eruption studied occurred from 2nd February and ended on 24th August 1922. It occurred in two locations, at 30-50 m above sea level (asl) (2nd -19th Feb) and between 900-1050 m asl (3rd of March - 24th August) (Haig, 1937; Géze, 1943; Fitton *et al*., 1983 and Déruelle, 1983). The lava flow is located at 9°1'W, 4° 1'N, 2 km south of Idenau and 10 km north of Debundscha. The lava is basaltic and typically pahoe-hoe lava, resulting from two viscous, fast flowing lava. The lava is smooth and has a ropy appearance. The surface of the lava now has plants and appears slimy and silky. Mean annual rainfall at Idenau is 8,392 mm, and that of Debundscha is 9086 mm (Fraser *et al*., 1998). The rainfall pattern is monomodal. The lava emerged from a crater at about 1,500 m asl, and moved 10 km from the crater to the sea. The flow is 1.5 km wide until it becomes divided at 170 m asl.

Sampling

Vegetation Survey

Fifteen plots of 20 m x 50 m, at a distance of 100 m from each other were located on the two edges, (1 plot each) and 13 plots in the centre of the flow. The plots were then surveyed using the Whittaker method as shown in **[[Figure 2]]** (Bullock, 1996). Plots were completely sampled in July 2001(rainy season), December 2001 (dry season), June 2002 and December 2002.

Plant species found on the different plots were identified, and their growth forms and distribution patterns noted. For each species, the number of individuals encountered in the plots was recorded. Information on modes of dispersal was obtained from collections from the Limbe Botanic Garden and other available literature. Voucher specimens were prepared, identified and deposited at the Limbe Botanic Garden herbarium (SCA).

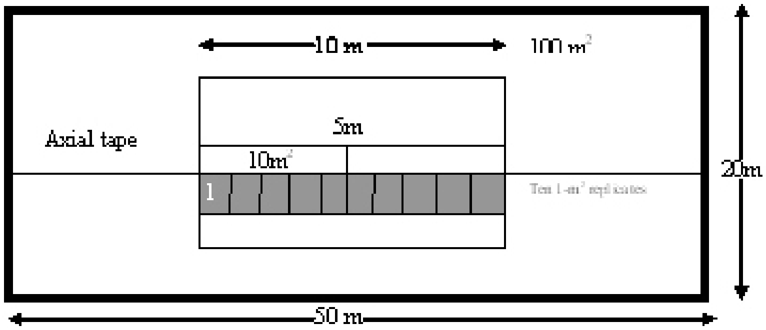

Fig. 2: Plot Layout by Whittacker's method

Soil Survey

Topsoil samples at 0-5 cm depth were collected from each of the plots in triplicates and bulked. Using standard procedures the following soil characteristics were determined.

Soil texture, Soil reaction (pH in H2O and in KCL), Organic Matter and Organic Carbon using the Walkley and Black method (Cottenie *et al*., 1982), Total Phosphorous, (using Bray's II method), Total Nitrogen was determined using a modified Kjedahl method, Exchangeable cations (Ca, Mg, K, and Na) were extracted and read using the Atomic Absorption. Spectrophotometer (AAS), CEC was determined using 1M Ammonium Acetate at pH 7 and 1 M KCl at pH 8.2, Amorphous Fe and Al using colorimeter (Blakemore *et al.*, 1981), Free Fe, Mn, Zn and Cu using AAS, Phosphorus retention (Blakemore *et al*., 1987).

Data Processing and Analysis

The Minitab (13.1) was used to analyse data collected.

Plant species were sorted out into different life forms. The species diversity was determined using Shannon-Weaver Diversity Index ($H+$):

$Hi=-\Sigma(pi)(\ln pi)$

Where pi = proportion of all individual in the samples belonging to species i (Magaurran, 1988).

Simpson's Diversity Index (1/D), was also used to compute the diversity of the species.

Where $D = \Sigma\ (pi)\ 2$

Jaccard's coefficient was used to calculate the similarity indices of species between plots in the lava.

Jaccard's coefficient

$(Cj) = J / (a = b - j)$

Where

J = Number of species common to both sites.

a = Number of species in site A

b = Number of species in site B (Fowler *et al.*, 1998; Krebs, 1999)

Species composition, basal areas and densities were also calculated.

The soil data were analysed using principal component analysis.

Results

Species Abundance

A total of 102 species belonging to 40 families were collected (Table 1 and Appendix 1). Seventy-four (74) of them were flowering plant species (belonging to 29 families), with 21 tree species belonging to 13 families, 13 shrubs belonging to 7 families, and 33 herbaceous species including 13 orchids belonging to 11 families, 7 climbers (belonging to 5 families), 17 fern species (belonging to 8 families), 5 mosses, 4 lichens, and 2 unidentified fungi species were also collected.

Table 1: Species abundance on the 1922 lava flow classified by family and life forms

	Different Lifeform	No of Families	No of Species	
	Flowering plants	29	74	
	Climbers	5	7	
	Herbs	10	20	
	Orchids	1	13	
	Shrubs	7	13	
	Trees	13	21	
	Ferns	8	17	
	Fungi	1	2	
	Lichens	1	4	
	Mosses	1	5	
	Total	47	102	

[[Figure 3]] shows, that the Orchidaceae was the most represnted family, with 13 species, while the Rubiaceae was the most represented tree family with 8 tree species. The Asteraceae, Poaceae, and Musci had 5 species each. Six other families had 3 species, 5 with 2 species and 18 with only a single species.

Table 2 shows 106 trees with dbh between 1-10 cm, belonging to 18 species and 10 families. The mean dbh was 3.65 cm and the mean total basal area (BA) was 1885.3 cm2.

Table 3 shows some quantitative characteristics of the vegetation found on the 1922 lava flow. The basal areas (BA), ranged from less than 1 cm2 in *Mangifera indica* to over 500 cm2 in *Alchornea cordifolia.* Relative densities (relden) value were generally less than 10%) except for *Syzygium guineense* that had the highest relative density (16.81 %), a relative abundance of 40.83 %, CVI. of 57.63 % and IVI of 68.74%. *Mangifera indica* had the lowest, relative density (0.84 0%), relative abundance (0.42 %) and CVI (0.88 %).

Species Similarity

Species similarities between the different plots in the lava are shown in **[[Figure 4]]** and Appendix II. The distance correlation coefficient (ward linkage) showed that the lava has two main types of plant communities based on their similarity indices. The first type includes plots 1, 2, 3, 5, 6, 4 and 7. The main species peculiar to this community include *Croton gratissimus, Melanthera scandens, Ageratum conyzoides, Elaeis guineensis, Psorospermum standis, Harungana madagascariensis, Solenostemon monostachyus and Dissotis rotundifolia.* The main plant species belonging to the second type include *Centrosema virginianum* and *Trichomanes africanum*.

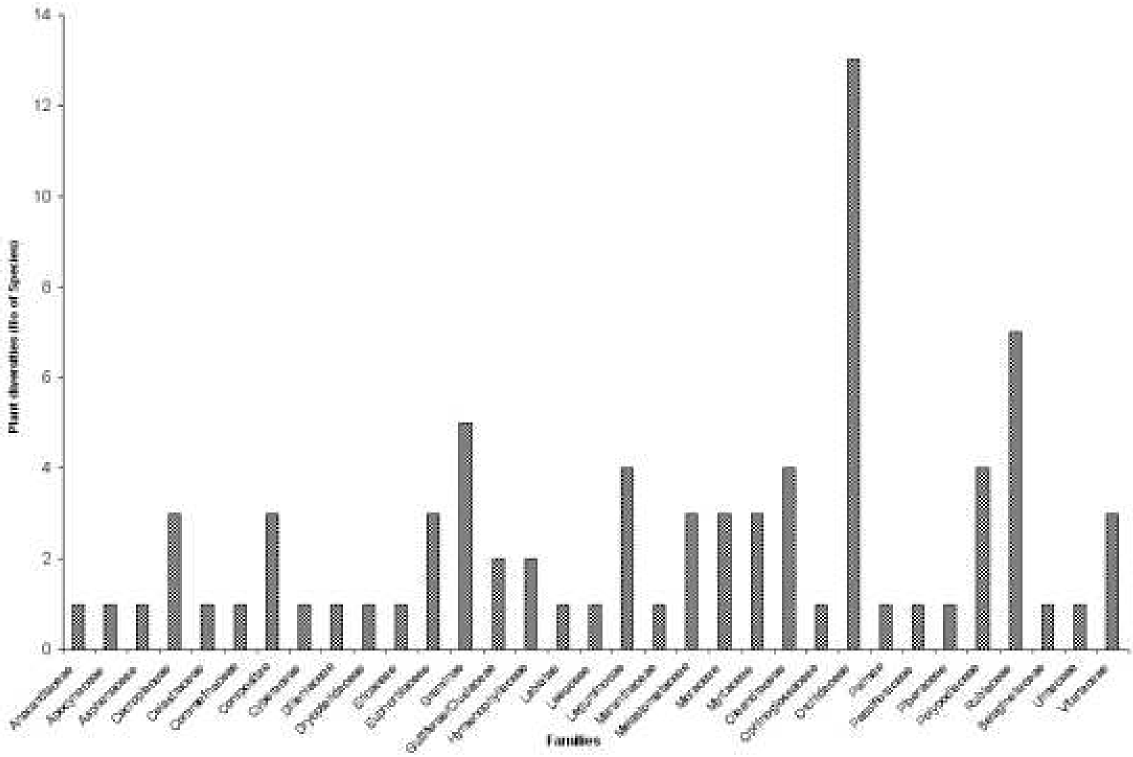

Fig. 3 Frequency of Plant Species found of different Families and Groups on the 1922 lava flow

No	Species	Family	Codes	Lifeform	No of Plants (nb)	DBH (cm)
1	*Albizia zygia*	Leguminosae/Mimosaceae	Alzy	Tree	3	3
2	*Alchornea cordifolia*	Euphorbiaceae	Alco	Tree	19	6
3	*Alstonia boonei*	Apocynaceae	Albo	Tree	1	2.2
4	*Bridelia micrantha*	Euphorbiaceae	Brmi	Tree	3	3
5	*Cecropia cecropioides*	Cecropiaceae	Cece	Tree	7	5
6	*Ficus lutea*	Moraceae	Filu	Tree	7	5
7	*Ficus sur*	Moraceae	Fisu	Tree	5	3.5
8	*Harungana madagascariensis*	Guttiferae/Clusiaceae	Hama	Tree	6	3.5
9	*Mangifera indica*	Anacardiaceae	Main	Tree	1	1
10	*Musanga cecropioides*	Cecropiaceae	Muce	Tree	4	3.8
11	*Psidium guajava*	Myrtaceae	Psqu	Tree	2	2.3
12	*Syzygium guineense*	Myrtaceae	Sygu	Tree	20	7
13	*Syzygium* sp.	Myrtaceae	Sysp	Tree	2	3.8
14	*Trema orientalis*	Ulmaceae	Tror	Tree	2	1

Mean dbh = 3.65 cm

Table 2: Families with tree species with DBH 1-10cm in the 2001-02 surveys on the 1922 lava flow.

Species	Family	**Code**	**Life forms**	**BA (cm2)**	**Relden (%)**	**RelDom (%)**	**CVI (%)**	**Freq**	**RelFreq**	**IVI (%)**
Macaranga occindentalis	Euphorbiaceae	Maoc	Tree	3.14	0.84	0.17	1.01	1	0.79	1.80
Alstonia boonei	Apocynaceae	Albo	Tree	3.80	0.84	0.20	1.04	1	0.79	1.84
Mangifera indica	Anacardiaceae	Main	Tree	0.79	0.84	0.04	0.88	2	1.59	2.47
Trema orientalis	Ulmaceae	Tror	Tree	1.57	1.68	0.08	1.76	2	1.59	3.35
Hymenodictyon biafranum	Rubiaceae	Hybi	shrub	3.54	1.68	0.19	1.87	3	2.38	4.25
Psidium guajava	Myrtaceae	Psqu	Tree	8.31	1.68	0.44	2.12	4	3.18	5.30
Tetracera alnifolia	Dilleniaceae	Teal	Tree	2.356	2.52	0.13	2.65	4	3.18	5.82
Albizia zygia	Leguminosae/Mimosaceae	Alzy	Tree	21.21	2.52	1.13	3.65	3	2.38	6.03
Bridelia micrantha	Euphorbiaceae	Brmi	Tree	21.21	2.52	1.13	3.65	3	2.38	6.03
Syzygium sp.	Myrtaceae	Sysp	Tree	22.68	1.68	1.20	2.88	7	5.56	8.44
Psorospermum staudtii	Guttiferae/Clusiaceae	Psst	shrub	12.57	3.36	0.67	4.03	6	4.76	8.79
Musanga cecropioides	Cecropiaceae	Muce	Tree	45.37	3.36	2.41	5.77	7	5.56	11.32
Ficus sur	Moraceae	Fisu	Tree	48.11	4.20	2.55	6.75	10	7.94	14.69
Mussaenda tenuiflora	Rubiaceae	Mute	Climber	7.85	8.40	0.42	8.82	10	7.94	16.76
Harungana madagascariensis	Guttiferae/Clusiaceae	Hama	Tree	57.73	5.04	3.06	8.10	11	8.73	16.83
Cecropia cecropioides	Cecropiaceae	Cece	Tree	137.44	5.88	7.29	13.17	5	3.97	17.14
Tarenna conferta	Rubiaceae	Taco	Shrub	43.26	14.28	2.29	16.58	7	5.56	22.14
Ficus lutea	Moraceae	Filu	Tree	137.44	5.88	7.29	13.17	12	9.52	22.70
Alchornea cordifolia	Euphorbiaceae	Alco	Tree	537.21	15.97	28.49	44.46	14	11.11	55.57
Syzygium guineense	Myrtaceae	Sygu	Tree	769.69	16.81	40.83	57.63	14	11.11	68.74
TOTALS				**1885.3**	**100**	**100**	**200.00**	**126**	**100.00**	

Table 3: The basal area, relative densities, relative abundances, cover value indices, frequencies, relative frequencies and the important value indices of species on the 1922 lava flow.

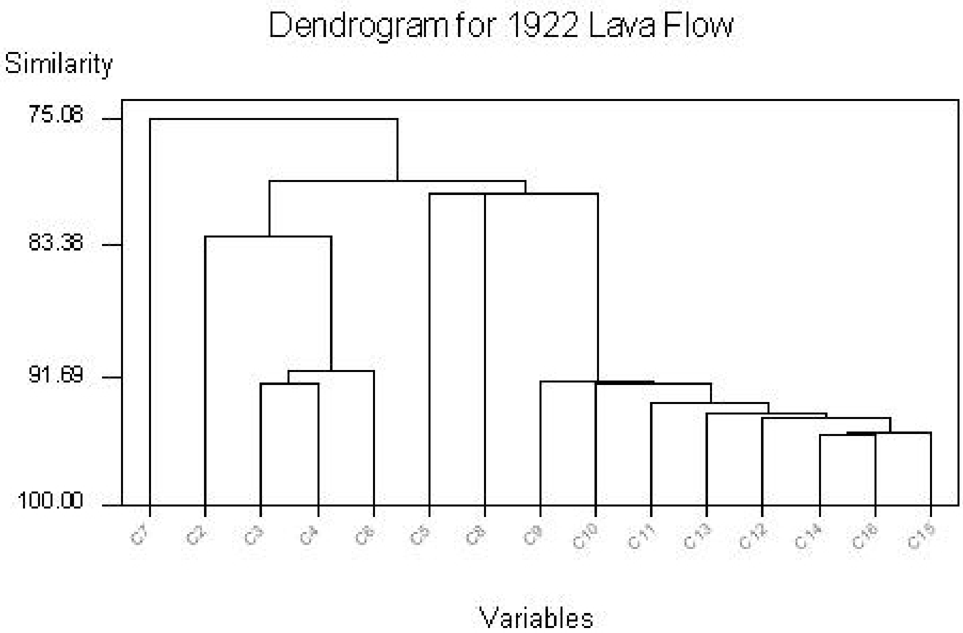

Fig. 4: Dendrogram showing similarity between different plots on the 1922 lava flow

Soil Analysis

The soil profile of the lava flows is given in Table 4 below.

Table 4: The soil profile of the 1922 lava flow on Mt Cameroon.

Parameter	**Centre**	**Right edge**	**Left edge**
Colour	Very dark grey (5Y311)	Dark reddish brown (5Y313)	Dark reddish brown (5Y3/4)
Top Soil	More organic matter about (1 cm thick)	Sandy loamy soil (3cm thick)	Loamy soil, silt moisture with clay about 3.5cm thick
Horizon B.	Hard parent rock	Gravel thin layer	Gravel thin layer.

The chemical and physical properties of soils collected from the edges and the centre of the lava flow are given in Table 5.

Texture

Table 5 shows that the sand content was highest on the right wing, with 56.5 % sand, while the centre and the left edges had 16.8 % and 19.3 % respectively. There is no front since this lava flowed into the sea. Silt is highest in the left wing (69 %), while it is lowest in the right wing (39 %). The clay content is highest in the centre (15 %) and lowest in the right wing (5 %).

	Particle Size Analysis %			PH		Organic Matter				
	Sand	**Silt**	**Clay**	**H2O**	**KCl**	**%C**	**%N**	**C/N**	**%P Retention**	**Total %P**
Centre	16.8	68	15	4.62	4.31	1.10	3.53	31.4	51.02	19.30
Right Wing	56.5	39	5	5.31	4.66	4.44	1.65	27.0	50.64	21.88
Left Wing	19.3	69	12	5.05	4.55	3.70	2.40	15.4	48.20	27.13
	Exchangeable	**Cations**		**Meq/100g**			**Micronutrients**	**%**		
	Ca	**Mg**	**K**	**Na**	**CEC Meq/100g**	**Base Structure %**	**Total Fe**	**Liberated Fe**	**Amorphous Fe**	**Amorphous Al**
Centre	2.72	0.56	1.44	0.08	4.81	9	1.69	7.63	3.02	5.34
Right Wing	2.89	1.16	0.28	0.01	3.34	13	0.92	4.82	10.81	5.66
Left Wing	2.42	0.44	0.28	0.03	3.19	11	0.00	8.9	3.85	5.66

Table 5: Chemical analysis of soil from the 1922 lava flow on Mt Cameroon

Organic Carbon (Org C)

A comparison of the sampled sites shows that the centre on the 1922 lava had the highest Org C, while the left wing had the lowest (3.7 %).

Organic Matter (OM)

In 1922 lava flow, the centre had the highest OM (19.1%) while the left wing had the lowest OM (3.7 %).

Total Nitrogen (Tot N)

The total N is highest in the 1922 lava flow (3.53 %). Comparing the different sites at the 1922 lava, the centre had the highest Tot N (3.53 %) while the right wing had the lowest (1.65 %).

Exchangeable Cations

On the 1922 lava, Ca content is highest on the right edge (2.89 Meq/100g) and lowest in the left edge (2.42 Meq/100g). In the case of Mg, it is highest at the centre (0.46 Meq/100g) and lowest on the right edge (0.16 Meq/100g). The centre was richest in K and Na (1.44 Meq/100g and 0.08 Meq/100g)

Phosphorus Retention (P-Ret)

The amount of phosphorus retained in the soil on the 1922 lava is low (51.02 %). At the individual sites, the 1922 lava's left edge had the lowest (48.2 %) and the lava's centre, the highest (51.02 %).

Iron (Fe)

No soluble Fe was registered on the left edge of the lava but there was 7.63% liberated Fe and 10.81% amorphous Fe in it.

Principal Component Analysis (PCA) of Soil

Eigen-analysis**(Table 6a.)** shows that the first two components PC1 and PC2 explain 100% of the total variation. **Table 6b** indicates that PC1 is most strongly affected by the Na, K, CEC, base saturation, Org. C, and OM, Total Nitrogen, soluble Fe, and soil clay content. PC2 is strongly associated with Ca, C/N, P and sand-silt content.

Comparing Soil and Vegetation

The Principal Correlation Analysis of soil in relation to vegetation and sites shows that the main soil contents that affect vegetation are soil texture, Org C and OM, on the lava. In relation to vegetation composition and diversity, the soil sand content, Org C and OM, strongly affect vegetation development, while soil texture, pH (H2O, KCl and NaF), CEC, Base saturation, Total N and P, P-Retention, Fe, Soluble Fe, Liberated Fe, Amorphous Fe and Al are associated and closely related to vegetation development.

Discussion

The 1922 lava flow is located on the west coast of Mt. Cameroon. In this area the rainfall pattern is mono-modal and high, especially in Idenau and Debundscha. Fraser *et al*., (1998) reported that Debundscha is the second wettest region of the world with a mean annual rainfall of 9,086 mm (from 1965 - 1993) after Charrapanjee in India.

Debundscha is only about 1 Km from the sea and the 1922 lava flow where the flux of the wet monsoon winds influence precipitation. With this high precipitation the soils do not completely get dry, even when it does not rain for some days (Cable and Check, 1998).

According to Juvik and Merlin (2001) the type of lava also affects colonization patterns. The pahoe-hoe favours more plant diversity than the aa lava. This is because the cracks and fissures in pahoe-hoe, favour accumulation of rainfall and trap inorganic and organic particles from the surrounding impervious lava surface while the aa lava boulder fields are ubiquitous. This results in a lack of plant growth. The pahoe-hoe cracks also have thermal properties more conducive for plant growth. This maybe due to the persistent cloud cover and mist coupled with high rainfall, temperature and distance from the seacoast (Payton, 1993).

Throughout the year, the temperature is between 22°C - 30°C in Debundscha at an altitude of about 20 m asl. In Idenau at 40 m asl it ranges between 20°C - 30°C (Fraser *et al*., 1998; Tchouto, 1996). This may be because there is a gentle breeze blowing from the sea and that the air movements are very slow, thus modifying the temperature. Cable and Cheek (1998) reported that there are no hurricanes in this region.

Table 6a: Eigen-analysis of the Correlation Matrix 1922 Lava

	PC1	**PC2**	**PC3**
Eigenvalue	15.119	6.881	0.000
Proportion	0.687	0.313	0.000
Cumulative	0.687	1.000	1.000

Table 6b :

Variable	PC1	PC2	PC3
C2	-0.185	-0.264	0.135
C3	0.169	0.287	0.023
C4	0.222	0.191	-0.099
C5	-0.254	-0.060	0.179
C6	-0.256	-0.033	0.333
C7	-0.257	-0.000	0.115
C8	0.244	-0.118	-0.144
C9	0.244	-0.119	0.263
C10	0.253	0.070	-0.130
C11	0.138	-0.321	0.125
C12	-0.011	-0.381	0.006
C13	0.215	0.209	-0.004
C14	0.251	-0.085	0.266
C15	0.257	0.022	0.097
C16	0.245	-0.116	-0.126
C17	0.245	-0.116	-0.126
C18	-0.152	0.307	0.055
C19	0.106	-0.348	0.001
C20	0.179	-0.273	0.139
C21	-0.180	-0.272	0.129
C22	-0.178	-0.275	-0.719
C23	-0.251	0.085	-0.160

Where		
C2 = sand	C9 = Org. Matter (%)	C16 = S/CECE (%)
C3 = Total silt	C10 = Tot. N (g/kg)	C17 = CEC 7
C4 = Clay	C11 = C/N	C18 = Brays P2 (ppm)
C5 = pH H2O	C12 = Ca	C19 = P-ret (%)
C6 = pH KCl	C13 = Mg	C20 = Soluble Fe (g/kg)
C7 = pH NaF	C14 = K	C21 = Liberated Fe
C8 = Org. C (%)	C15 = Na	C22 = Amorphous Fe
		C23 = Amorphous Al

The mean annual relative humidity, on this Southwestern flank ranges between 75 % and 80 %. Generally, the climate is of the equatorial regime covering the entire land of the Atlantic oceanic plain. Rosevear conducted the first recolonization study on lava flows on Mt Cameroon in 1936 and 1937 on the 1922 eruption, fourteen years after it occurred (cited by Keay, 1959). Eighty years after the eruption, it is observed that the vegetation has moved from the mosses, lichens and ferns as observed by Rosevear, to a dominant shrubby forest with 74 flowering plant species belonging to 29 families, the family Orchidaceae being the most dominant. This is in contrast with the findings of Ndam *et al*. (2002), who stated after a survey, conducted in 1995, that in the third stage of succession, 90% of orchids disappear. The vegetation presently comprises of a semi- dense, forest 4-5 m tall with emergent that are 10-25 m tall. The co-dominant trees (about 40% of all those greater than 6 cm dbh recorded, and generally the tallest of all trees present) are *Syzygium guineense* var. *littorale* and *Alchornea cordifolia*. Fraser *et al.*, (1999) and Ndam, (2000) reported the presence of *Syzygium guineense*, during their 1995 survey. *Lannea* was not observed during this survey. This may be as a result of logging for fuel wood, which has already started on the lava flow (fig 5). The main trees and large shrubs, in descending order of importance (% of all trees between 1-10cm dbh) are *Syzygium guineense* (16.81%), *Alchornea cordifolia* (15.97%) and *Tarenna conferta* (14.29%). Seedlings of *Tarenna conferta*, in shrub surveys conducted done by Fraser *et al.*, 1999 and Ndam *et al.*, 2002, were shown to dominate those of smaller woody plants.

Some of the species found in the centre of the lava flow were not present on the edges. Plant diversity was higher in the centre than the edges. This may be as a result of the lava flow being surrounded by palm plantations (*Elaies guineensis*) and also because of the age of the lava (Déreulle *et al.*, 1987).

Shannon-Weaver and Simpson's Diversity Indices show that plant diversity is high as should be expected. They are 3.58 and 22.86 respectively, higher than those determined by Ndam *et al.* (2002) on the same lava in 1995 (3.1057 and 16.4201 respectively). This shows that plant diversity has increased. The Basal Area of 0.785m2/h was far less than that observed by Ndam (1998). This may be as a result of the logging for fuel wood that is going on in the area.

Species richness was highest on the edges probably because at this stage of succession, new species colonize from the edges. Thebaud and Stersberg (1997), while studying species colonization of 15, 48, 91 year old lava flows at Grand Bruté, la Reunion, observed that dispersal on the15 year old lava flow was stochastic but found that large sized plants on the old lava flows (e.g. 91 years) tended to grow from the edge at a very slow rate (less than 1 m per year). They also observed that most colonizing species are wind-dispersed. A similar observation was reported by Ndam *et al.,* (2002) on the 1922 lava flow and by Robyns(1932) in Kiva and Krakatua. This could also be due to the thickness of the lava at the centre compared to the edges (Fitton *et al*. 1983).

The Dendogram produced from the similarity indices shows that plants of the same species and life forms were found both on the edges and in the centre. Although the lava is chemically uniform, its structure can be variable resulting in differences in the colonization process (Bachelery, 1981). Another possible reason given earlier by Robyns (1932) for these differences could be that erosion from adjacent land, deposits soil on the edges of lava flows, favouring the development of species that are not adapted to grow on the dry rock environment. This is in contrast with our findings. Species diversity is higher in the centre of the 1922 lava flow as a result of differences in the soil parameters. The amounts of organic matter and organic carbon from analyses were highest in the centre (19.10 and 11.10 % respectively). On the edges they were 4.07 and 7.1 % respectively. The main reason for the contrast of our findings with earlier reports may be that the lava is moving towards a more mature structure. The climatic conditions of the area could also be wielding an influence. According to Fraser *et al*. (1998), the area has the highest amount of rainfall in the country. This, coupled with the high temperature and humidity, leads to rapid decomposition of organic matter resulting in fast soil formation. The topography (gentle sloping and flat) and lava type (pahoe-pahoe) also influence disintegration of the surface rock and soil formation.

It could be said that the successional pathway on lava flow starts with lichens and mosses, followed by a second stage characterised by the presence of all other life forms, with woody species and climbers being the least abundant or even absent.

Lava Profile

The profile of the lava flow is divided into 2 horizons. The topsoil is 10 cm dbh did not conform to this observation. Comparing the observed data on species composition, basal area and plant density on the lava with those of other researchers showed some differences, which may be attributed to the logging for fuelwood -already taking place there. This means that colonization may be very difficult to assess.

The edaphic factors; climate (temperature between 19°C - 34°C), rainfall (between 227 - 9086 mm) and soil, play a very vital role on the plant colonization process. Also, the type and number of plant species tend to improve the nutrient level of the soil although the plants are selective to the type and amount of nutrients utilized. The soil pH is slightly acidic and tends to break down parent rock materials. Growing roots of trees also tend to break down the parent materials releasing nutrients. From our results it was found that soil texture, total Phosphorus, total Nitrogen, Organic matter, cation exchange capacity (CEC), exchangeable cations soil pH and Phosphorus retention strongly affect the plant colonization process on the lava flows of Mt Cameroon.

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APPENDIX I

List of species on the 1922 lava flow classified by family and life forms

	Family	***Plant***	**Sp**	**Code**	**Life**	**Mechanism**
		Names	**No**	**Code**	**Form**	**of dispersal**
1	**Convolvulaceae**	*Ipomoea batatas* (L.) Lam.		Ipba	Climber	Animal
2	**Convolvulaceae**	*Ipomoea involucrata* P. Beauv.		Ipin	Climber	Animal
3	**Convolvulaceae**	*Ipomoea* sp.	**3**	Ipsp	Climber	Animal
4	**Dilleniaceae**	*Tetracera alnifolia* Willd.	**1**	Teae	Climber	Animal
5	**Leeaceae**	*Leea guineensis* G. Don	**1**	Lequ	Climber	Animal
6	**Passifloraceae**	*Adenia lobata* (Jacq.) Engl.	**1**	Adlo	Climber	Wind
7	**Rubiaceae**	*Mussaenda tenuiflora* Benth.	**8**	Mute	Climber	Wind
8	**Aspleniaceae**	*Asplenium barteri* Hook.	**1**	Asba	Fern	Wind

9	**Dryopteridaceae**	*Ctenitis dimidiata* (Mett. Ex Kuhn)Tardieu	**1**	Ctdi	Fern	Wind
10	**Hymenophyllaceae**	*Trichomanes africanum* Christ.		Traf	Fern	Wind
11	**Hymenophyllaceae**	*Trichomanes borbonicum* Bosch	**2**	Trbu	Fern	Wind
12	**Oleandraceae**	*Arthropteris cameroonensis* Alston		Arca	Fern	Wind
13	**Oleandraceae**	*Nephrolepis biserrata* (Sw.) Schott		Nebi	Fern	Wind
14	**Oleandraceae**	*Nephrolepis cordiflora*	**4**	Neco	Fern	Wind
15	**Oleandraceae**	*Nephrolepis pumicicola* Ballard		Nepu	Fern	Wind
16	**Ophioglossaceae**	*Ophioglossum reticulatum* L.		Opre	Fern	Wind
17	**Polypodiaceae**	*Anapeltis lycopodioides* (L.) J.Sm.	**4**	Anly	Fern	Wind
18	**Polypodiaceae**	*Microgramma owariensis* (Desv.) Alston		Miow	Fern	Wind
19	**Polypodiaceae**	*Microsorum punctatum* (L.) Copel.		Mipu	Fern	Wind
20	**Polypodiaceae**	*Microsorum scolopendria* (Burm.f.)Copel		Misc	Fern	Wind
21	**Selaginellaceae**	*Selaginella* sp.	**1**	Sesp	Fern	Wind
22	**Vittariaceae**	*Antrophyum mannianum* Hook.		Anma	Fern	Wind
23	**Vittariaceae**	*Loxogramme abyssinica* (Baker)M.G.Price	**3**	Loab	Fern	Wind
24	**Vittariaceae**	*Loxogramme lanceolata*(Sw.)C.Presl		Lola	Fern	Wind
25	**Fungi**	*Unidentified*		0	Fungi	Wind
26	**Fungi**	*Unidentified*	**2**	0	Fungi	Wind
27	**Commelinaceae**	*Commelina diffusa* Burm.f.	**1**	Codi	Herb	Animal

28	**Compositae**	*Chromolaena odorata* (L.)R.M. King &H.Robinson		Chod	Herb	Wind
29	**Compositae**	*Crassocephalum crepidioides* (Benth.) S.Moore		Crcr	Herb	Wind
30	**Compositae**	*Emilia coccinea* (Sims.)G. Don		Emco	Herb	Wind
31	**Compositae**	*Melanthera scandens* (Schumach.& Thonn.)Roberty	**5**	Mesc	Herb	Wind
32	**Compositae/Asteraceae**	*Ageratum conyzoides* L.		Agco	Herb	Wind
33	**Cyperaceae**	*Mariscus alternifolius* Sensu Hooper	**1**	Maal	Herb	Animal
34	**Euphorbiaceae**	*Phyllanthus amarus* Schumach. & Thonn.	**5**	Pham	Herb	Animal
35	**Fabaceae**	*Pueraria phaseolioides* (Roxb) Benth.	**3**	Puph	Herb	Animal
36	**Fabaceae**	*Centrosema virginiana* (L.) Benth.	**2**	Cevi	Herb	Animal
37	**Gramineae**	*Hyparrhenia rufa* (Nees) Stapf.	**5**	Hyru	Herb	Wind
38	**Gramineae**	*Panicum maximum* Jacq.		Pama	Herb	Wind
39	**Gramineae**	*Paspalum conjugatum* Berg		Paco	Herb	Wind
40	**Gramineae**	*Pennisetum hordeoides* (Lam.) Steud.		Peho	Herb	Wind
41	**Gramineae/Poaceae**	*Axonopus compressus* (Sw.) P. Beauv.		Axca	Herb	Wind
42	**Labiatae/Lamiaceae**	*Solenostemon monostachyus (*P.Beauv.) Briq.		Somo	Herb	Wind
43	**Marantaceae**	*Megaphrynium macrostachyum (*Benth.) *Milne-Redh.*	**1**	Mema	Herb	Animal
44	**Melastomataceae**	*Dissotis rotundifolia(*Sm.)*Triana*		Diro	Herb	Animal
45	**Piperaceae**	*Piper umbellatum* L.	**1**	Pium	Herb	Animal

46	**Rubiaceae**	*Diodia sarmentosa* Sw.		Disa	Herb	Animal
47	**Lichens**	*Coccocarpia* sp.		Cosp	Lichens	Wind
48	**Lichens**	*Dictyonema* sp.		Disp	Lichens	Wind
49	**Lichens**	*Leptogium* sp.		Lesp	Lichens	Wind
50	**Lichens**	*Parmelia laevigata*	**4**	Pala	Lichens	Wind
51	**Musci**	*Campylopus dusenii* C.M		Cadu	Moss	Wind
52	**Musci**	*Campylopus horridus* Welw.&Duby		Caho	Moss	Wind
53	**Musci**	*Ectropothecium afro-molluscum (*C.M) Broth.Keay		Ecmu	Moss	Wind
54	**Musci**	*Ectropothecium regulare* (Brid.)Jaeg		Ecre	Moss	Wind
55	**Musci**	*Sematophyllum calspitosum (*Sw) Mitt Sensu lato H.n.Dixon	**5**	Seca	Moss	Wind
56	**Orchidaceae**	*Ancistrochilus rothschildianus* O'Brien		Anro	Orchid	Wind
57	**Orchidaceae**	*Ancistrorhynchus cephelotes*		Ance	Orchid	Wind
58	**Orchidaceae**	*Angraecum birrimense* Rolfe		Anbi	Orchid	Wind
59	**Orchidaceae**	*Bulbophyllum bifarium* Hook.f.		Bubi	Orchid	Wind
60	**Orchidaceae**	*Bulbophyllum calvum* Summerh		Buca	Orchid	Wind
61	**Orchidaceae**	*Bulbophyllum calyptratum* Kraenzl.		Buca	Orchid	Wind
62	**Orchidaceae**	*Bulbophyllum intertextum* Lindl.		Buin	Orchid	Wind
63	**Orchidaceae**	*Bulbophyllum josephii* (Kuntze) Summerh. *var. josephii*		Bujo	Orchid	Wind
64	**Orchidaceae**	*Bulbophyllum simonii* Summerh.		Busi	Orchid	Wind
65	**Orchidaceae**	*Hebenaria* sp.	**13**	Hesp	Orchid	Wind

66	**Orchidaceae**	*Polystachya affinis* Lindl.		Poaf	Orchid	Wind
67	**Orchidaceae**	*Polystachya tessellata* Lindl.		Pote	Orchid	Wind
68	**Orchidaceae**	*Polystachya laxiflora* Lindl.		Polu	Orchid	Wind
69	**Costaceae**	*Costus afer* Ker Gawl.	**1**	Coaf	Shrub	Animal
70	**Euphorbiaceae**	*Croton gratissimus* Burch.		crhi	Shrub	Animal
71	**Guttiferae/Clusiaceae**	*Psorospermum staudtii* Engl.		Psst	Shrub	Wind
72	**Malavaceae**	*Urena lobata* L.	**1**	Urlo	Shrub	Animal
73	**Melastomataceae**	*Dissotis erecta* (Guill. & Perr.)Dandy		Dier	Shrub	Animal
74	**Melastomataceae**	*Tristemma hirtum* P.Beauv.	**3**	Trhi	Shrub	Animal
75	**Mimosoidae**	*Mimosa pudica* L.		Mipu	Shrub	Animal
76	**Rubiaceae**	*Hymenodictyon biafranum* Hiern		Hybi	Shrub	Wind
77	**Rubiaceae**	*Oldenlandia lancifolia* (Schumach.) DC.		Olla	Shrub	Animal
78	**Rubiaceae**	*Pauridiantha venusta* N.Halle		Pave	Shrub	Animal
79	**Rubiaceae**	*Tarenna conferta* (Benth.)Hiern		Taco	Shrub	Animal
80	**Rubiaceae**	*Tarenna* sp.		Tasp	Shrub	Animal
81	**Rubiaceae**	*Tricalysia discolor* Brenan		Trdi	Shrub	Animal
82	**Anacardiaceae**	*Magifera indica* L.	**1**	Main	Tree	Animal
83	**Apocynaceae**	*Alstonia boonei* De Wild.	**1**	Albo	Tree	Animal
84	**Cecropiaceae**	*Cecropia cecropioides*		Cece	Tree	Animal
85	**Cecropiaceae**	*Cecropia peltata*		Cepe	Tree	Animal
86	**Cecropiaceae**	*Musanga cecropioides* R.Br. ex Tedlie	**3**	Muce	Tree	Animal
87	**Celastraceae**	*Maytenus* sp.	**1**	Masp	Tree	Animal
88	**Ericaceae**	*Agauria salicifolia* (Comm.ex Lam.)Hook.f.ex Oliv.	**1**	Agsa	Tree	Animal

89	**Euphorbiaceae**	*Alchornea cordifolia* (Schum. $ Thonn.)Mull.Arg.		Alco	Tree	Animal
90	**Euphorbiaceae**	*Bridelia micrantha* (Hochst.)Baill.		Brmi	Tree	Animal
91	**Euphorbiaceae**	*Macaranga occidentalis* (Mull.Arg.)Mull.Arg.		Maoc	Tree	Animal
92	**Fabaceae**	*Desmodium adscendens* (Sw.)DC. var.*adscendens*		Dead	Tree	Animal
93	**Guttiferae/Clusiaceae**	*Harungana madagascariensis* Lam. Ex Poir.	**2**	Hama	Tree	Bird
94	**Mimosaceae**	*Albizia zygia* (DC.)J.F.Macbr.		Alzy	Tree	Wind
95	**Moraceae**	*Ficus conraui* Warb.	**3**	Fico	Tree	Animal/Bird
96	**Moraceae**	*Ficus lutea* Vahl		Filu	Tree	Animal/Bird
97	**Moraceae**	*Ficus sur* Forssk.		Fisu	Tree	Animal/Bird
98	**Myrtaceae**	*Psidium guajava* L.	**3**	Psqu	Tree	Animal
99	**Myrtaceae**	*Syzygium guineense* (Wild.)DC		Sygu	Tree	Animal
100	**Myrtaceae**	*Syzygium* sp.		Sysp	Tree	Animal
101	**Palmae**	*Elaies guineensis* Jacq.	**1**	Elgu	Tree	Animal/Rodents
102	**Ulmaceae**	*Trema orientalis* (L.)Blume	**1**	Tror	Tree	Animal

Appendix: II Similarity Index (Jaccard's) on the different plots in the 1922 lava flow.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0	0.452	0.368	0.320	0.373	0.310	0.267	0.231	0.203	0.226	0.233	0.210	0.233	0.193	0.190
2.		0	0.467	0.544	0.361	0.281	0.403	0.387	0.361	0.367	0.356	0.328	0.379	0.321	0.316
3.			0	0.585	0.352	0.270	0.478	0.448	0.350	0.333	0.345	0.386	0.345	0.286	0.327
4.				0	0.319	0.250	0.567	0.463	0.382	0.442	0.431	0.423	0.404	0.340	0.360
5.					0	0.581	0.299	0.358	0.353	0.360	0.347	0.340	0.375	0.363	0.386
6.						0	0.224	0.333	0.325	0.300	0.316	0.342	0.389	0.419	0.452
7.							0	0.500	0.440	0.449	0.408	0.489	0.390	0.286	0.333
8.								0	0.583	0.600	0.742	0.719	0.543	0.500	0.581
9.									0	0.559	0.594	0.677	0.500	0.552	0.586
10.										0	0.667	0.700	0.613	0.517	0.552
11.											0	0.750	0.548	0.615	0.593
12.												0	0.531	0.593	0.630
13.													0	0.500	0.536
14.														0	0.850
15.															0