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## TAXONOMIC DIVERSITY OF LIANAS AND VINES IN FOREST FRAGMENTS OF SOUTHERN TOGO

Kouami KOKOU<sup>1</sup>, Pierre COUTERON<sup>2</sup>, Arnaud MARTIN<sup>3</sup> & Guy CABALLÉ<sup>3+</sup>

### RÉSUMÉ

Ce travail analyse la contribution des plantes grimpantes, ligneuses et herbacées, à la biodiversité des îlots forestiers du sud du Togo. Sur la base d'un inventaire floristique général (649 espèces) couvrant 17,5 ha dans 53 îlots, 207 espèces de lianes, herbacées grimpantes et arbustes grimpants ont été recensées, soit 32 % de la flore (représentant 135 genres et 45 familles). La plupart sont de petite taille, traînant sur le sol ou s'accrochant à des arbres et arbustes ne dépassant pas 8 m de hauteur.

Une analyse factorielle des correspondances a permis de caractériser chacun des trois types d'îlots existants (forêt littorale, forêt semi-caducifoliée et galerie forestière) par plusieurs groupements exclusifs de plantes grimpantes. La dominance des herbacées grimpantes et des arbustes grimpants (132 espèces) sur les lianes *sensu stricto* (75 espèces de ligneuses grimpantes) est révélatrice de forêts plutôt basses, à canopée irrégulière. Environ 60 % des plantes grimpantes du sud Togo sont communes aux forêts tropicales de la côte ouest africaine.

### SUMMARY

This work analyses the contribution of climbing plants to the biodiversity of forest fragments in southern Togo, West Africa. Based on a general floristic inventory totalling 17.5 ha of 53 forest fragments, there were found to be a total of 649 species; lianas, vines or climbing shrubs represented 135 genera in 45 families, *i.e.* 207 species or 32 % of the plant diversity. The majority of these climbing plants were small, grew along the ground or were attached to shrubs or trees no more than 8 m in height.

When only climbing plants were considered, it was possible to distinguish three fragment forest types (littoral, semi-deciduous, gallery) using correspondence analysis. The dominance of non-lianas (132 species of vines and climbing shrubs) over lianas *sensu stricto* (75 species) is indicative of relatively low forest having an irregular canopy. Approximately 60 % of climbing plants in southern Togo are common to the tropical forests of the western coast of Africa.

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## INTRODUCTION

Although lianas (woody climbers) and vines (herbaceous climbers) are characteristic elements of tropical forests, their role in forest dynamics remains poorly understood (Putz, 1984; Gentry & Dodson, 1987; Putz & Chai, 1987; Gentry, 1991; Hegarty & Caballé, 1991; Balfour & Bond, 1993). Paucity of information concerning lianas partly results from the difficulty to count them correctly because of their long, often tangled aerial extensions and multiple rooting (Caballé, 1977, 1980, 1994; Peñalosa, 1984; Garcia Alvez, 1989; Castellanos *et al.*, 1992; Putz, 1995; Troy *et al.*, 1997). Furthermore, numbers and density of lianas vary considerably from continent to continent, forest to forest and even from site to site within the same forest, making it very difficult to interpret results of studies, even if climbing plants are surveyed (Emmons & Gentry, 1983; Caballé, 1984; Putz, 1990; Faber-Langendoen & Gentry, 1991; Gentry, 1993; Siebert, 1993; Phillips & Gentry, 1994; Makana *et al.* 1998).

Liana and vine settlement in a given location requires a sufficient number of suitably-sized supports and full light exposition. In forests, the first of these conditions is often easily met as trees offer an immense array of forms both in terms of size and morphology (Putz, 1985, 1995; Clark & Clark, 1990; Heaney & Proctor, 1990; Coudurier, 1992; Yap *et al.*, 1995); and, the second condition is fulfilled mostly along forest margins or ecotones (Florence, 1981; Caballé, 1986; Lee, 1988; Castellanos, 1991; Gartner, 1991; Lee & Richards, 1991; During *et al.*, 1994). In continuous forest blocks, such situations may be provided by a concentration of treefall gaps and/or by special topographic features (*e.g.* riverbanks or uplands). In contrast, fragmentation of forest blocks allows the diversification of edges and augments both number and area of sites that are favourable for the development of vine and liana communities (Williams-Linera, 1990; Laurance, 1991; Crome, 1993; Jarvis, 1995).

The present study aims at assessing the importance of liana and vine communities for forest fragments located in the "Dahomey gap" that marks an interruption in the continuous forest block of West Africa (Jenik, 1994; Maley, 1996). To our knowledge, this is the first study dealing with a forest environment that offers a high concentration of favourable sites for climber communities. The contribution of lianas and vines to plant diversity is here analysed. Diversity of lianas and vines communities is examined in the light of paleogeographical characteristics of forest fragments in the Dahomey gap.

## MATERIALS AND METHODS

### VEGETATION OF SOUTHERN TOGO

Togo is situated in the Dahomey gap, which represents the interruption of the West African tropical forest at the level of the Gulf of Guinea (IUCN, 1992). No large tracts of forest are observable in Togo except the mountain forests of the South-West (Akpagana, 1992). However, there are numerous forest fragments, particularly in the south (Kokou, 1998; Kokou *et al.*, 1999b and c). Most of these forest fragments are protected by local people either as sacred sites or as firebreaks. In "sacred groves", local people conduct ceremonies to enter into

contact with gods or deceased ancestors (Kokou *et al.*, 1999a). The “firebreak” forests are close to villages and screen them from bush fires coming from neighbouring savannas.

Climate in southern Togo is sub-equatorial with a main rainy season from March to July (maximum precipitation in June), and a minor rainy season from September to November (maximum precipitation in October). In an average year, there is a geographic gradient of precipitation (L’Hote & Mahé, 1996), with rainfall increasing from the littoral (800 mm/yr.) towards the interior (1 000 - 1 250 mm/yr.). Relative humidity is constantly high and often greater than 80 %. Annual temperatures average 27° C with an annual mean variation of about 4° C.

#### FOREST FRAGMENTS CHARACTERIZATION

Three main types of forest fragments have been previously identified in southern Togo (Kokou *et al.*, 1999c). The first one (coastal forest) is observed on sands and coastal deposits and is homologous to the “outlier forest” described in south-east Ghana by Hall & Swaine (1981). The second type is referred to as dry semi-deciduous (Hall & Swaine, 1981), and displayed some affinities with the *Celtis* and *Triplochiton* forest type described in Ivory Coast by Guillaumet & Adjanohoun (1971). In Togo, such forests are observed on soils developed on metamorphical rocks and also on Tertiary continental deposits. The last type consists in forest galleries which grow on hydromorphic soils located along the river network.

Coastal forests had a sparse canopy reaching 15 and 20 m in height, with an understorey displaying a high density of plants less than 2 m. Dry semi-deciduous forests were taller (above 20 m), with a closer canopy and a sparser understorey. Forest galleries displayed a physiognomy that was highly variable in terms of canopy height and vertical stratification, though the understorey was always very dense.

#### LIANAS AND VINES CHARACTERIZATION

The description of the principal categories of climbing plants is over a hundred years old (*e.g.* Darwin, 1867; Treub, 1883a and b; Schenck, 1892). Nowadays, classifications used are quite similar, differing only in detail. One important aspect that most modern classifications share is the integration of “dimensions”, functional or adaptive of the different kinds of climbers (*e.g.* Caballé, 1986; Hegarty, 1989 or Putz & Holbrook, 1991).

We classified climbing plants into three categories: woody climbing plants (lianas), herbaceous climbing plants (vines), and climbing shrubs. The latter are usually upright but can be non-self-supporting and climbing (= lianescent); they were treated as lianas (*e.g.* Caballé, 1993, 1998).

#### GENERAL CENSUS: COLLECTION AND ANALYSIS OF DATA

The interpretation of aerial photographs from missions IGN 1976-79 followed by field verification allowed the mapping of all the 296 forest fragments in southern Togo (under 7° north latitude). From this map, 53 forest fragments (*i.e.*

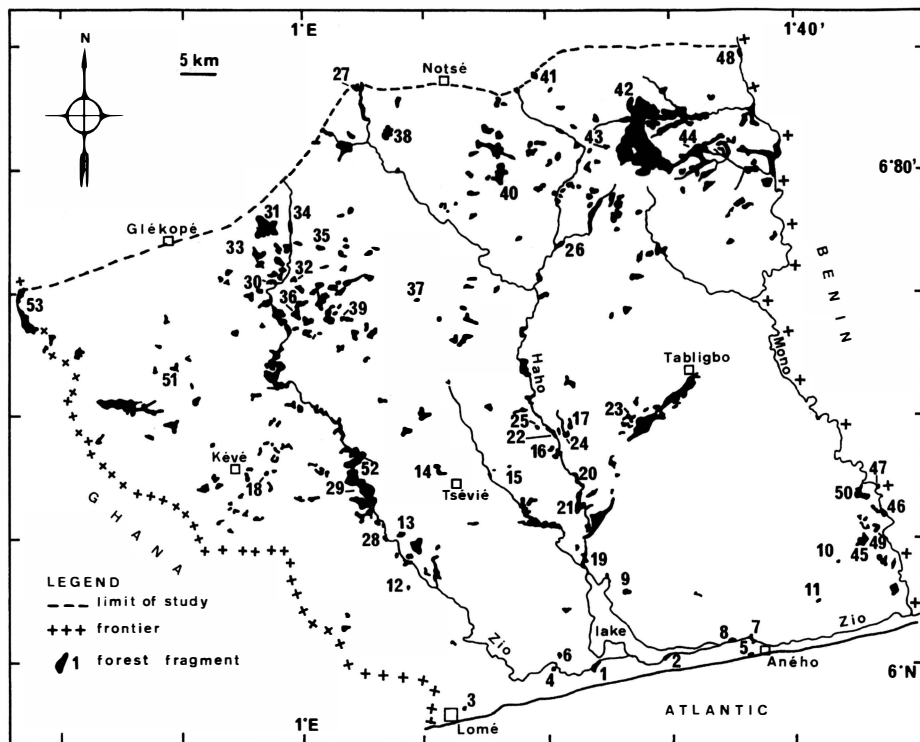


Figure 1. — Forest fragments of southern Togo.

20 % of the total) were randomly chosen for field investigations (Fig. 1). Their size ranged between 1 ha and 3 658 ha with 23 fragments less than 10 ha, 17 between 10-50 ha, and 13 greater than 50 ha. Field plots (50 m by 10 m) were established along transect lines that were laid out in order to intersect both core and edge areas in each sampled forest fragment. Three hundred and forty-four plots were established with a total area amounting to 17.2 ha.

The presence of all plant species, regardless of size and life form, was recorded in each plot. A list of all angiosperms and pteridophytes found in the plots was compiled (Kokou, 1998; Kokou *et al.*, 1999b). Species in the list were classified according to the four phytogeographical categories (*i.e.* Guineo-Congolese, transition, Sudano-Zambeziyan, introduced) provided by Aké Assi (1984).

Distribution of lianas and vines in the 53 sampled fragments was investigated through Correspondence Analysis (CA; Benzecri, 1973; Hill 1973a) applied to a species fragment contingency table. Each cell of this table contained the number of plots from a given fragment within which a given species was recorded.

A pairwise analysis of species co-occurrence within plots was used to gain a detailed understanding of climber associations. For each pair of climbing species, the relative frequency of co-occurrence was tested following an approach proposed by Gauthier *et al.* (1977) and based on Fisher's exact test (Siegel, 1956).

Diversity of lianas and vines has been quantified by means of usual indices (Hill, 1973b; Daget, 1980), such as:

- \* Species richness ( $N_0$ ), which represents the total number of species;
- \* Shannon diversity index ( $I_{SH}$ ), given by:

$$I_{SH} = \sum_{i=1}^n pi \log ( pi )$$

where  $n$  = number of encountered species and  $pi$  = probability that a species occurrence within a plot corresponds to species  $i$ . In practice,  $pi = qi/Q$  where  $qi$  is the number of plots wherein species  $i$  was observed, and  $Q = \sum_{i=1}^n qi$ .

## RESULTS

### CLIMBER DIVERSITY AND FLORISTIC RICHNESS

The complete floristic inventory yielded 649 species of which 207 or 32 % were climbers. Climbing plants of all types numerically outstrips other life forms: 14 % trees, 25 % self-supporting shrubs, 26 % upright herbs and 3 % other. Of the climbing plants, 111 were vines, 75 lianas and 21 climbing shrubs. These last can become climbers and are listed in Table I.

TABLE I

#### *List of climbing shrub species.*

*Byrsocarpus(=Rourea) coccineus* Schum. & Thonn. (Connaraceae)  
*Cnestis ferruginea* DC. (Connaraceae)  
*Connarus thonningii* (DC.) Schellenb. (Connaraceae)  
*Dalbergia altissima* Bak. f. (Leg. Papilionoideae)  
*Macrosphyra longistyla* (SW.) DC. (Rubiaceae)  
*Maytenus ovatus* var. *ovatus* (Wall. ex Wight & Arn.) Loes. (Celastraceae)  
*Mimosa pigra* L. (Leg. Mimosoideae)  
*Nauclea latifolia* Sm. (Rubiaceae)  
*Pancovia sessiliflora* Hutch. & Dalz. (Sapindaceae)  
*Plumbago zeylanica* L. (Plumbaginaceae)  
*Premna quadrifolia* Schum. & Thonn. (Verbenaceae)  
*Quisqualis indica* L. (Combretaceae)  
*Ritchiea duchesnei* (De Wild.) Keay (Capparaceae)  
*Ruspolia hypocrateriformis* (Vahl.) Milne (Acanthaceae)  
*Sorindeia warneckeii* Engl. (Anacardiaceae)  
*Strychnos usambarensis* Gilg (Loganiaceae)  
*Uvaria chamae* P. Beauv. (Annonaceae)  
*Uvaria doeringii* Diels (Annonaceae)  
*Uvaria ovata* subsp. *ovata* (Dunal) A. DC. (Annonaceae)  
*Uvaria sofa* Sc. Elliot (Annonaceae)  
*Vangueriopsis spinosa* (Schum. & Thonn.) Hepper (Rubiaceae)

With regards to regional phytogeography, 60 % of the liana and vine species are related to forests of tropical Africa (*i.e.* Guineo-Congolese), 32 % are characteristic of the forest-savanna transition, 3 % are typical of savannas that encircle the forest fragments (*i.e.* Sudano-Zambesian), and 5 % represent introduced species.

The 207 climbing plant species are members of 135 genera and 45 families. Leguminosae (Papilionoideae), Asclepiadaceae, Rubiaceae, Cucurbitaceae, Apocynaceae and Convolvulaceae account for the greatest number of genera and species (Table II). For all forest fragments, the most frequent lianas were *Cissus petiolata* (recorded in 197 plots), *Byrsocarpus coccineus* (195), *Secamone afzelii* (180), *Grewia carpinifolia* (170) and *Triclisia subcordata* (162). These are all indigenous species.

TABLE II

*The ten most common plant families.*

Family	Number of	
	genera	species
Leg. Papilionoideae	18	27
Asclepiadaceae	12	18
Rubiaceae	12	13
Cucurbitaceae	10	13
Apocynaceae	6	10
Convolvulaceae	5	17
Leg. Mimosoideae	5	6
Menispermaceae	5	5
Vitaceae	4	10
Annonaceae	3	6
Others	55	82
Total	135	207

Liana and vine richness did not correlate with the number of plots inventoried (Table III) nor with the surface area of the forest fragments (Spearman's rank correlation,  $r_s = 0.34$ ,  $n = 53$ ,  $p < 0.0001$ ), nor even with the distance to small cities and villages ( $r_s = 0.26$ ,  $n = 53$ ,  $p < 0.0001$ ). Gallery forests were the least inventoried (86 plots) and yet they supported the greatest climbing plant richness and highest diversity as measured by the Shannon Index ( $I_{SH} = 1.89$ ). Notwithstanding, the share of each forest fragment type was about one third of the total number of climbing plants.

#### SIZE AND LAYERING

Among the lianas and vines inventoried, very few (9 %) were large and reached the canopy of trees greater than 8 m in height. Most (65 %) grew attached

TABLE III

*Plant species richness, and liana and vine diversity according to forest type.*

Forest type	Number of			Shannon diversity index ( $I_{SH}$ )	Number of		Most common families (number of genera, species)
	plots	climbers	species		genera	families	
Littoral	146	219	69	1.62	58	28	Asclepiadaceae (9, 10) Leg. Papilionoideae (7, 9) Cucurbitaceae (5, 6) Vitaceae (4, 5) Rubiaceae (3, 4) Capparaceae (2, 4)
Semi-deciduous	112	441	142	1.84	97	36	Leg. Papilionoideae (13, 21) Asclepiadaceae (10, 14) Rubiaceae (8, 9) Apocynaceae (5, 7) Vitaceae (4, 9) Convolvulaceae (4, 8) Annonaceae (3, 6)
Gallery	86	499	154	1.89	108	41	Leg. Papilionoideae (13, 20) Rubiaceae (12, 13) Asclepiadaceae (10, 15) Apocynaceae (6, 10) Convolvulaceae (5, 10) Menispermaceae (5, 5) Cucurbitaceae (4, 6) Annonaceae (3, 6)

to or supported by trees and shrubs between 2-8 m high. The remaining (26 %) grew along the ground. This heavy occupation of the understory by lianas and vines is reflected in the fact that 96 % of forest fragments have relatively closed lower stratas that impeded human penetration. The ground-cover by liana and vine was 70 - 90 % (of total area inventoried), as estimated by orthogonal projection.

#### FOREST TYPES AND ASSOCIATIONS OF CLIMBING PLANTS

Figure 2 shows the distribution of the 53 forest fragments in the first factorial plane of the correspondence analysis. The first axis (8.13 % of total inertia) discriminates the gallery forests. The second axis (5.96 %) differentiates between littoral and semi-deciduous forests. The three forest types are hence characterized on the sole basis of the climbing plants (207 species) they harbour. Moreover, very similar results were obtained when the correspondence analysis relied on the entire flora (649 species) of the forest fragments (Kokou *et al.*, 1999b, c; Kokou & Caballé, 2000). Furthermore, the relative frequency of the most frequent climber species depends upon forest fragment type (Table IV).

Tests on species co-occurrences enabled a more precise distinction between climber associations within each type of forest fragments (appendix). In coastal

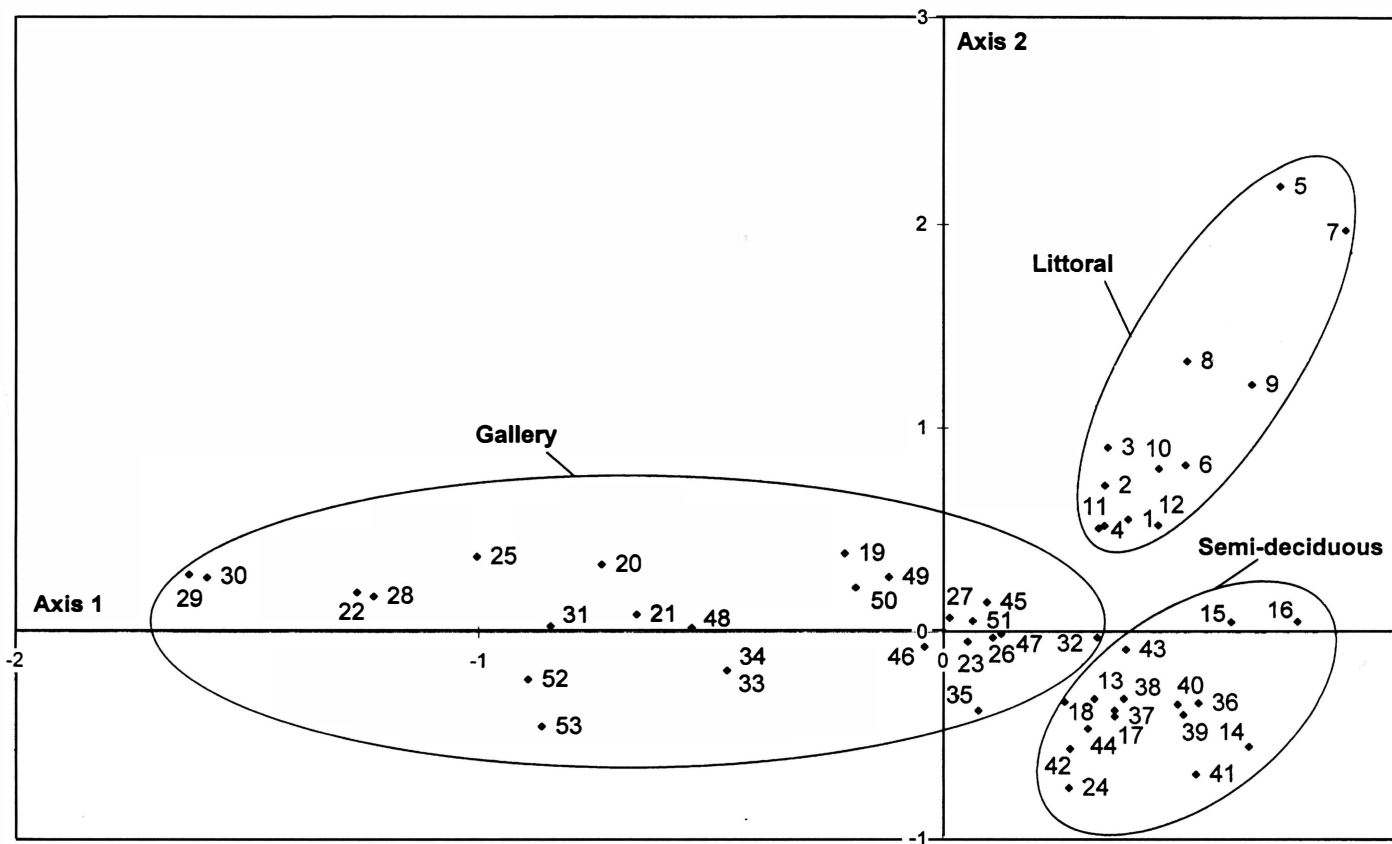


Figure 2. — Results of correspondence analysis of 53 forest fragments (in 1 - 2 factorial plane). Number refers to forest fragment.

TABLE IV

*Most frequent plant species according to forest type.*

Species (Family)	Littoral	Semi-deciduous	Gallery
<i>Dichapetalum pallidum</i> (Oliv.) Engl. (Dichapetalaceae)	+++	-	-
<i>Grewia carpinifolia</i> Juss. (Tiliaceae)	+++	-	-
<i>Rüchhia reflexa</i> (Thonn.) Gilg & Benedict (Capparaceae)	+++	-	-
<i>Secamone afzelii</i> (Schultes) K. Schum. (Asclepiadaceae)	+++	++	-
<i>Uvaria chamae</i> P. Beauv. (Annonaceae)	+++	-	-
<i>Sorindeia warneckei</i> Engl. (Anacardiaceae)	++	-	+
<i>Byrsocarpus coccineus</i> Schum. & Thonn. (Connaraceae)	-	+++	-
<i>Cissus petiolata</i> Hook. f. (Vitaceae)	-	+++	-
<i>Motandra guineensis</i> A. DC. (Apocynaceae)	-	+++	-
<i>Griffonia simplicifolia</i> (Vahl. ex DC.) Baill. (Leg. Caesalpinioideae)	-	++	++
<i>Paullinia pinnata</i> L. (Sapindaceae)	-	-	+++
<i>Trichlisia subcordata</i> Oliv. (Menispermaceae)	-	-	+++
<i>Combretum afzelii</i> Engl. & Diels (Combretaceae)	-	-	++
<i>Cremaspora triflora</i> (Thonn.) K. Schum. (Rubiaceae)	-	-	+
<i>Flagellaria guineensis</i> Schumach. (Flagellariaceae)	-	-	+
<i>Gymnema sylvestre</i> (Retz.) Schultes (Asclepiadaceae)	-	-	+

Species present in inventories: +++ &gt; 50 %, ++ &gt; 40 %, + &gt; 30 %, - &lt; 30 %.

forests, four associations were identified on the basis of 15 species. In semi-deciduous forests, 9 associations were defined on the basis of 40 species. One association containing *Momordica charantia* was identified as peripheral to the fragments. This species often covers trees along edges of fragments or around clearings, and then withers and entirely disappears during the dry season (Kokou & Caballé, 2000). In other semi-deciduous forests, the liana *Cardiospermum grandiflorum* displays the same behaviour. In gallery forests, there were 9 associations defined from 45 climber species (appendix).

## DISCUSSION

In southern Togo, climbing plant richness (207 species) is high compared to the overall forest flora (649 species). The only known examples of areas similarly rich in climbing plants are secondary or perturbed forests (Kahn, 1982; Putz & Chai, 1987; Pinard & Putz, 1994; Dewalt *et al.*, 2000). Forest fragments of southern Togo are effectively protected by local people and the multiplication of forest edges is probably the factor that determines the development of climbing plant communities.

Climbing plants of southern Togo represent about one third of the flora, of which lianas *sensu stricto* (75 species) make up only 11.6 % while vines (111 species) contribute 17.1 % and climbing shrubs (21 species) 3.2 %. The comparatively high percentage of vines and climbing shrubs as opposed to lianas is indicative of largely open forest environments lacking a true high, closed canopy. Most of the vines and lianas were climbing (< 8 m) trees or shrubs. Another indication of the openness of the upper strata of fragment forests comes from the prevalence of vines and, to a lesser extent, lianas from the families Asclepiadaceae, Cucurbitaceae, Convolvulaceae and Vitaceae (Table II). Conversely, tall African forests with closed canopies are characterized by few vines and more lianas Apocynaceae, Hippocrateaceae, Dichapetalaceae, Annonaceae, Combretaceae, and Loganiaceae (see Caballé, 1986; Gentry, 1991). The presence of a relatively high number of climbing shrub species is also a characteristic of forests with a low and irregular canopy. In the gallery forests, climbing plant diversity is at a maximum and may be explained by the amplification of edge effects. On the other hand, littoral forest fragments are the least rich (Table III), and their lianescent flora conforms to the general rule that littoral and coastal areas are floristically poor.

The estimation of abundance and richness of climbing plants in an area can vary enormously depending upon whether inventorying included lianas of small diameter (*e.g.* DBH < 2.5 cm), climbing herbaceous plants (vines), and certain forms of hemi-epiphytes and epiphytes. It is evident from published literature that vines and lianas are frequently not recognized as distinct life forms. Furthermore, life forms or growth habits are rarely clearly defined or differentiated (*e.g.* hemi-epiphytes are often confounded with lianas) and usually only plants with DBH  $\geq$  5 or 10 cm are inventoried (Hegarty & Caballé, 1991; Orians *et al.*, 1996). These facts make it difficult to interpret different results and to compare different studies. Future progress in the understanding of climbing plant ecology depends upon resolving these conceptual and technical discrepancies. A universal agreement upon definitions of climbing plant strategies and harmonized inventory protocols is imperatively required.

Jacobs (1976) estimated that lianas compose 8 % of the tropical flora world-wide. Gentry & Dodson (1987) found that of the flora of seven humid tropical forest sites, 19 % of the species were lianas. Denslow (1996) found that lianas and vines made up 10.3 % of deciduous moist forest (Barro Colorado, Panama) and 22.5 % of premontane wet forest (La Selva, Costa Rica). At two dry forest sites in Central America, Lott (1985) reported the composition of lianescent species to be 24 %. In two evergreen forests in the north of the Democratic Republic of Congo (formerly Zaire), Makana *et al.* (1998) estimated liana richness

to be about 30 %. Caballé (1986) found that in the north-east of Gabon in evergreen forest naturally perturbed by numerous treefall gaps, lianas can represent up to 37 % of species having a DBH  $\geq$  5 cm (10 ha inventoried). In the same forest in north-eastern Gabon, Hladik (1974, 1978) found that liana leaves formed 36 % of annual litter production. Conversely, in the Chocó in Colombia, one of the richest forests in the world, Faber-Langendoen & Gentry (1991) found that lianas (11 species/ha) represented less than one per cent of tree species richness (250 species/ha).

Perhaps the most surprising result of this study is that a discrimination between forest types can be achieved on the sole basis of the floristic composition of climbing vegetation. Each forest type can be defined by several exclusive associations of climbers: 4 for littoral, 9 for semi-deciduous and 9 for gallery forest fragments (appendix). Such a result suggests that the dynamism of climbing plant communities is not solely determined by the number of plant interfaces and edges created by perturbation and/or fragmentation of forest areas (Williams-Linera, 1990; Laurance, 1991; Crome, 1993; Phillips & Gentry, 1994; Jarvis, 1995). Albeit that the majority of climbing plants depend upon other plants to develop, they are just as important a life form as any other making up the plant community. Climbing plants are an intrinsic and important component of the biodiversity of tropical areas. This is even more true in the African continent, which possesses the largest number of lianas (Putz & Mooney, 1991).

## APPENDIX

### *Groups of lianas and vines according to three forest types.*

#### Littoral

Species	Sign	Freq	Species	Sign	Freq
<i>Dichapetalum pallidum</i>		89	<i>Opilia amentacea</i>		81
<i>Sorindeia warneckeii</i>	+++	127	<i>Uvaria chamae</i>	+++	138
<i>Uvaria chamae</i>	+++	138	<i>Ancylobothrys scandens</i>	+++	101
<i>Ancylobothrys scandens</i>	+++	101	<i>Ritchiea reflexa</i>	+++	134
<i>Capparis erythrocarpos</i>	+++	87	<i>Dichapetalum pallidum</i>	+++	89
<i>Ritchiea reflexa</i>	+++	134	<i>Sorindeia warneckeii</i>	+	127
<i>Ruspolia hypocrateriformis</i>	+	35	<i>Capparis erythrocarpos</i>	+	87
<i>Strychnos barteri</i>		80	<i>Grewia carpinifolia</i>		170
<i>Ruspolia hypocrateriformis</i>	+++	35	<i>Secamone afzelii</i>	+++	180
<i>Landolphia togolana</i>	+++	94	<i>Ritchiea reflexa</i>	+++	134
<i>Capparis erythrocarpos</i>	+++	87	<i>Uvaria chamae</i>	+	138
<i>Dichapetalum pallidum</i>	+++	89	<i>Uvaria ovata ovata</i>	+	23
<i>Ancylobothrys scandens</i>	++	101	<i>Adenia lobata</i>	+	119

## Semi-deciduous

Species	Sign	Freq	Species	Sign	Freq	Species	Sign	Freq
<i>Uvaria sofa</i>		45	<b><i>Premna quadrifolia</i></b>		61	<b><i>Dioscorea preussii</i></b>		28
<i>Barleria opaca</i>	+++	40	<i>Barleria opaca</i>	+++	40	<i>Motandra guineensis</i>	+++	85
<i>Artabotrys velutinus</i>	+++	48	<i>Motandra guineensis</i>	+++	85	<i>Cryptolepis sanguinolenta</i>	+++	19
<i>Motandra guineensis</i>	+++	85	<i>Strophanthus hispidus</i>	+++	37	<i>Mondia withei</i>	+++	35
<i>Strophanthus hispidus</i>	+++	37	<i>Ritchiea capparoides</i>	+++	61	<i>Parquetina nigrescens</i>	+++	61
<i>Griffonia simplicifolia</i>	+++	103	<i>Tragia benthamii</i>	+++	19	<i>Combretum racemosum</i>	+++	49
<i>Momordica charantia</i>	+++	61	<i>Tragia senegalensis</i>	+++	36	<i>Strychnos soubrensis</i>	+++	49
<i>Tragia benthamii</i>	+++	19	<i>Triaspis odorata</i>	+++	26	<i>Adenia cissampeloides</i>	+++	59
<i>Hippocratea indica</i>	+++	102	<i>Rhynchosia buettneri</i>	+++	30	<i>Cremaspora triflora</i>	+++	54
<i>Strychnos soubrensis</i>	+++	49	<i>Adenia cissampeloides</i>	+++	59	<i>Premna quadrifolia</i>	+++	61
<i>Jasminum pauciflorum</i>	+++	63	<i>Mussaenda elegans</i>	+++	31	<i>Barleria opaca</i>	++	40
<i>Rhynchosia densiflora</i>	+++	51	<i>Artabotrys velutinus</i>	++	48	<i>Artabotrys velutinus</i>	+	48
<i>Mussaenda elegans</i>	+++	31	<i>Parquetina nigrescens</i>	++	61	<i>Cayratia gracilis</i>	+	13
<i>Premna quadrifolia</i>	+++	61	<i>Griffonia simplicifolia</i>	++	103	<b><i>Asparagus warneckeii</i></b>		83
<i>Asparagus warneckeii</i>	+++	83	<i>Rhynchosia densiflora</i>	++	51	<i>Barleria opaca</i>	+++	40
<i>Strophanthus sarmentosus</i>	++	23	<i>Mucuna pruriens</i>	+	20	<i>Artabotrys velutinus</i>	+++	48
<i>Triaspis odorata</i>	++	26	<i>Cremaspora triflora</i>	+	54	<i>Motandra guineensis</i>	+++	85
<i>Adenia cissampeloides</i>	++	59	<b><i>Ritchiea duchesnei</i></b>		17	<i>Strophanthus hispidus</i>	+++	37
<i>Parquetina nigrescens</i>	+	61	<i>Barleria opaca</i>	+++	40	<i>Ritchiea capparoides</i>	+++	61
<i>Ritchiea capparoides</i>	+	61	<i>Motandra guineensis</i>	+++	85	<i>Jasminum pauciflorum</i>	+++	63
<b><i>Dioscorea togoensis</i></b>		60	<i>Ritchiea capparoides</i>	+++	61	<i>Rhynchosia densiflora</i>	+++	51
<i>Uvaria doeringii</i>	+++	12	<i>Strychnos soubrensis</i>	+++	49	<i>Premna quadrifolia</i>	+++	61
<i>Cryptolepis sanguinolenta</i>	+++	19	<i>Mussaenda elegans</i>	+++	31	<i>Capparis thoningii</i>	++	50
<i>Rhynchosia densiflora</i>	+++	51	<i>Hippocratea indica</i>	++	102	<i>Momordica charantia</i>	+	61
<i>Ampelocissus bombycina</i>	+++	18	<i>Tiliacora funifera</i>	++	106	<i>Triaspis odorata</i>	+	26
<i>Mezoneuron benthamianum</i>	++	34	<i>Asparagus warneckeii</i>	+	83	<i>Tiliacora funifera</i>	+	106
<i>Momordica charantia</i>	++	61	<i>Uvaria sofa</i>	+	45	<i>Adenia cissampeloides</i>	+	59
<i>Abrus canescens</i>	++	30	<b><i>Adenia cissampeloides</i></b>		59	<i>Cremaspora triflora</i>	+	54
<b><i>Cremaspora triflora</i></b>		54	<i>Motandra guineensis</i>	+++	85	<b><i>Rhynchosia buettneri</i></b>		30
<i>Artabotrys velutinus</i>	+++	48	<i>Momordica charantia</i>	+++	61	<i>Barleria opaca</i>	+++	40
<i>Adenia cissampeloides</i>	+++	59	<i>Artabotrys velutinus</i>	+++	48	<i>Motandra guineensis</i>	+++	85
<i>Motandra guineensis</i>	++	85	<i>Barleria opaca</i>	+++	40	<i>Parquetina nigrescens</i>	+++	61
<i>Abrus canescens</i>	++	30	<i>Strophanthus hispidus</i>	+++	37	<i>Griffonia simplicifolia</i>	+++	103
<i>Gongronema latifolium</i>	+	19	<i>Abrus canescens</i>	+++	30	<i>Tragia senegalensis</i>	+++	36
<i>Parquetina nigrescens</i>	+	61	<i>Gongronema latifolium</i>	+++	19	<i>Hippocratea indica</i>	++	102
<i>Mezoneuron benthamianum</i>	+	34	<i>Ritchiea capparoides</i>	++	61	<i>Mondia withei</i>	+	35
<i>Ritchiea capparoides</i>	+	61	<i>Hippocratea africana</i>	++	59			
<i>Trichlisia subcordata</i>	+	162	<i>Rhynchosia densiflora</i>	++	51			
			<i>Tragia benthamii</i>	+	19			

## Gallery

Species	Sign	Freq	Species	Sign	Freq	Species	Sign	Freq
<b><i>Paullinia pinnata</i></b>		66	<b><i>Flagellaria guineensis</i></b>		29	<b><i>Culcasia scandens</i></b>		27
<i>Gymnema sylvestre</i>	+++	37	<i>Gymnema sylvestre</i>	+++	37	<i>Gymnema sylvestre</i>	+++	37
<i>Tacazzea apiculata</i>	+++	20	<i>Tacazzea apiculata</i>	+++	20	<i>Tacazzea apiculata</i>	+++	20
<i>Tylophora sylvatica</i>	+++	27	<i>Combretum afzelii</i>	+++	30	<i>Tylophora sylvatica</i>	+++	27
<i>Combretum afzelii</i>	+++	30	<i>Ipomoea cairica</i>	+++	8	<i>Combretum zenkeri</i>	+++	4
<i>Combretum smeathmannii</i>	+++	15	<i>Merremia hederacea</i>	+++	8	<i>Connarus thonningii</i>	+++	26
<i>Connarus thonningii</i>	+++	26	<i>Stachyanthus occidentalis</i>	+++	31	<i>Lepistemon owariensis</i>	+++	29
<i>Lepistemon owariensis</i>	+++	29	<i>Triclisia subcordata</i>	+++	162	<i>Merremia hederacea</i>	+++	8
<i>Zehneria capillacea</i>	+++	20	<i>Paullinia pinnata</i>	+++	66	<i>Stachyanthus occidentalis</i>	+++	31
<i>Stachyanthus occidentalis</i>	+++	31	<i>Culcasia scandens</i>	+++	27	<i>Cissampelos mucronata</i>	+++	19
<i>Cissampelos mucronata</i>	+++	19	<i>Connarus thonningii</i>	++	26	<i>Triclisia subcordata</i>	+++	162
<i>Triclisia subcordata</i>	+++	162	<i>Piper guineense</i>	++	8	<i>Abrus pulchellus</i>	+++	30
<i>Entada mannii</i>	+++	16	<i>Combretum smeathmannii</i>	+	15	<i>Centrosema pubescens</i>	+++	14
<i>Abrus pulchellus</i>	+++	30	<i>Zehneria capillacea</i>	+	20	<i>Dioclea reflexa</i>	+++	9
<i>Centrosema pubescens</i>	+++	14	<i>Hippocratea apocynoides</i>	+	3	<i>Paullinia pinnata</i>	+++	66
<i>Diodia scandens</i>	+++	18	<i>Cissampelos mucronata</i>	+	19	<i>Cissus petiolata</i>	+++	197
<i>Ipomoea cairica</i>	++	8	<i>Dioclea reflexa</i>	+	9	<i>Combretum afzelii</i>	++	30
<i>Merremia hederacea</i>	++	8	<i>Cissus petiolata</i>	+	197	<i>Stictocardia beraviensis</i>	+	3
<i>Mucuna sloanei</i>	++	11	<b><i>Diodia scandens</i></b>		18	<i>Zehneria capillacea</i>	+	20
<i>Dioclea reflexa</i>	+	9	<i>Tacazzea apiculata</i>	+++	20	<i>Hippocratea apocynoides</i>	+	3
<b><i>Cissus petiolata</i></b>		197	<i>Tylophora sylvatica</i>	+++	27	<i>Entada mannii</i>	+	16
<i>Griffonia simplicifolia</i>	+++	103	<i>Combretum afzelii</i>	+++	30	<i>Psophocarpus palustris</i>	+	3
<i>Zehneria capillacea</i>	+++	20	<i>Lepistemon owariensis</i>	+++	29	<b><i>Abrus pulchellus</i></b>		30
<i>Cremaspora triflora</i>	+++	54	<i>Cissampelos mucronata</i>	+++	19	<i>Gymnema sylvestre</i>	+++	37
<i>Paullinia pinnata</i>	+++	66	<i>Entada mannii</i>	+++	16	<i>Tylophora sylvatica</i>	+++	27
<i>Parquetina nigrescens</i>	++	61	<i>Centrosema pubescens</i>	+++	14	<i>Tacazzea apiculata</i>	++	20
<i>Combretum afzelii</i>	++	30	<i>Connarus thonningii</i>	++	26	<i>Connarus thonningii</i>	++	26
<i>Tragia senegalensis</i>	++	36	<i>Gymnema sylvestre</i>	+	37	<i>Merremia hederacea</i>	++	8
<i>Gymnema sylvestre</i>	+	37	<i>Combretum smeathmannii</i>	+	15	<i>Zehneria capillacea</i>	++	20
<i>Combretum racemosum</i>	+	49	<i>Passiflora foetida</i>	+	9	<i>Combretum smeathmannii</i>	+	15
<i>Connarus thonningii</i>	+	26	<b><i>Cissampelos mucronata</i></b>		19	<i>Lepistemon owariensis</i>	+	29
<i>Rhynchosia buettneri</i>	+	30	<i>Gymnema sylvestre</i>	+++	37	<i>Stictocardia beraviensis</i>	+	3
<i>Premna quadrifolia</i>	+	61	<i>Tacazzea apiculata</i>	+++	20	<i>Cissampelos mucronata</i>	+	19
<b><i>Rhigiocarya racemifera</i></b>		7	<i>Tylophora sylvatica</i>	+++	27	<b><i>Hypselodelphys poggeana</i></b>		23
<i>Tetracera alnifolia</i>	+++	8	<i>Combretum afzelii</i>	+++	30	<i>Griffonia simplicifolia</i>	+++	103
<i>Stachyanthus occidentalis</i>	++	31	<i>Combretum smeathmannii</i>	+++	15	<i>Cissus petiolata</i>	+++	197
<i>Sherbournia calycina</i>	++	5	<i>Lepistemon owariensis</i>	+++	29	<i>Culcasia scandens</i>	+++	27
<i>Cissus aralioides</i>	++	15	<i>Merremia hederacea</i>	+++	8	<b><i>Flagellaria guineensis</i></b>	+++	29
<i>Smilax kraussiana</i>	++	5	<i>Zehneria capillacea</i>	+++	20	<i>Cardiospermum grandiflorum</i>	++	15
<i>Thunbergia cynanchyfolia</i>	+	8				<i>Connarus thonningii</i>	+	26
<i>Griffonia simplicifolia</i>	+	103				<i>Hippocratea indica</i>	+	102
						<i>Stachyanthus occidentalis</i>	+	31
						<i>Paullinia pinnata</i>	+	66

Names in bold characters are those of species found to form connections in the statistical analysis. They provide the identification of each group. Freq = Frequency. Significantly positive levels (see in Sign column): +++  $p < 0.00001$ , ++  $p < 0.0001$ , +  $p < 0.001$ .

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