Diversity, Family Dominance, Life Forms and Ecological Strategies of Forest Fragments Compared to Continuous Forest in Southwestern Côte d'Ivoire

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Source: Candollea, 66(2) : 255-262

Published By: The Conservatory and Botanical Garden of the City of Geneva (CJBG)

URL: https://doi.org/10.15553/c2011v662a2

Diversity, family dominance, life forms and ecological strategies of forest fragments compared to continuous forest in southwestern Côte d'Ivoire

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Abstract

BAKAYOKO, A., P. MARTIN, C. CHATELAIN, D. TRAORE & L. GAUTIER (2011). Diversity, family dominance, life forms and ecological strategies of forest fragments compared to continuous forest in southwestern Côte d'Ivoire. *Candollea* 66: 255-262. In English, English and French abstracts.

Extensive agriculture and timber exploitation are the principal causes of forest destruction in Ivory Coast. This country has an annual deforestation rate of 1.1 to 2.9% which is the highest in Africa. Most Ivorian forests consist of protected areas and of forest fragments embedded in a secondary landscape composed of a mosaic of cultivated fields, fallows and perennial crops plantations. Southwestern Côte d'Ivoire which is our study area, is one of the rare areas where we can still find significant continuous forests blocks (classified forests of Goin-Débé and Cavally, and Taï National Park). This part of Ivorian forest is rich in narrow endemic species (so-called Sassandriennes species) and is one of the hotspots of biodiversity. Considering the floristic characteristics of the study area, the human pressure which also extends to protected areas, and the disastrous consequences on the biodiversity, it becomes a critical issue to assess the impact of forest fragmentation on floristic composition and diversity. Results of this study indicate that impact of isolation and further direct human disturbances on forest fragments lead to an increase of secondary and pioneers strategies and liana life forms. However, resilience of a high proportion of

Résumé

BAKAYOKO, A., P. MARTIN, C. CHATELAIN, D. TRAORE & L. GAUTIER (2011). Diversité, dominance des familles, stratégies écologiques et types biologiques des fragments forestiers en comparaison des grands massifs forestiers du Sud-Ouest de la Côte d'Ivoire. *Candollea* 66: 255-262. En anglais, résumés anglais et français.

Les principales causes de la destruction des forêts en Côte d'Ivoire sont l'agriculture extensive et l'exploitation de bois d'œuvre. Avec un taux de déforestation annuel variant entre 1,1 et 2,9%, notre pays est le deuxième pays africain touché par la déforestation après Madagascar. Aujourd'hui, l'essentiel des formations forestières est constitué par les aires protégées et des fragments forestiers au sein d'un paysage secondaire constitué de cultures, de jachères et de plantations pérennes. Notre zone d'étude qui est le Sud-Ouest du pays, est l'une des rares zones où l'on trouve encore de grands blocs forestiers tels le Parc National de Taï et les forêts classées du Cavally et du Goin-Débé entre lesquels on rencontre de nombreux fragments très menacés du fait de la pression humaine. Cette partie de la Côte d'Ivoire est très riche en espèces endémiques dites Sassandriennes et est une zone de haute diversité biologique. Vu cette particularité floristique de la zone d'étude, la forte pression humaine qui commencent à s'étendre également dans les formations protégées et les conséquences désastreuses sur la biodiversité, il était urgent de mesurer l'impact de la fragmentation

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Submitted on June 15, 2011. Accepted on October 26, 2011.

primary species including Sassandriennes endemics in fragments induce an increase in global richness and diversity and demonstrate that promoting their conservation in southwestern Ivory Coast can substantially contribute to general conservation of plant species. Political authorities and conservation agencies should become aware of the urgent need of appropriate conservation policy for these forest fragments.

Key-words

Tropical forest – forest fragmentation – floristic study – diversity – ecological strategies – plant conservation – Africa

sur la composition floristique et la diversité. Les résultats de cette étude indiquent que l'impact de l'isolation et les perturbations d'origine humaine que subissent les fragments induisent une augmentation des espèces secondaires et pionnières sur le plan des stratégies écologiques, et des lianes pour ce qui est des types biologiques. Néanmoins, la résilience dans les fragments forestiers d'une importante proportion d'espèces primaires comprenant des endémiques Sassandriennes contribue à une augmentation de la richesse et de la diversité, démontrant que promouvoir leur conservation dans le sud-ouest de la Côte d'Ivoire participe de manière significative à la conservation des espèces végétales. Les autorités politiques et les acteurs de la conservation doivent prendre conscience de l'urgence de la mise en place d'une politique de conservation de ces fragments forestiers.

Introduction

Extensive agriculture and timber exploitation are the main causes of forest fragmentation and the consecutive loss of species habitat (SAUNDERS & al., 1991; ALEXANDRE, 1992; REED & al., 1996). In Ivory Coast, where the economy is principally based on agriculture, the forest situation is even more alarming. The annual rate of deforestation in Ivory Coast is between 1.1 and 2.9%. This is the second highest rate of deforestation of African countries after Madagascar (ACHARD & al., 2002). This habitat loss is directly linked with an increase of the rate of species extinction (ANOMA & AKÉ ASSI, 1989; CORLETT, 1992; TURNER & al., 1994).

Indeed several studies concerning the influence of fragmentation have been undertaken in many countries (LOVEJOY & al., 1986; KLEIN, 1989; LAURANCE, 1991, 1998, 2000; BIERREGAARD & al., 1992; FONSECA de SOUZA & BROWN, 1994; MALCOLM, 1994; CAMARGO & al., 1995; TURNER, 1996; VANDERMEER, 1996; FERREIRA & LAURANCE, 1997; THIOLLAY, 1997; BENITEZ-MALVIDO, 1998; LAURANCE & al., 1998a,b; WILLIAMS-LINERA, 2002; ARIM & BARBOSA, 2003; SHEIL & BRUSLEM, 2003; ZHU & al., 2004). However such studies in Africa are still scarce and little have adressed the influence of fragmentation on diversity in a context of diffuse but continuous human pressure.

Our investigation area is the southwestern part of Ivory Coast. This area is one of the rare ones where we can still finds large continuous forest blocks such National Park of Taï and the classified forests of Cavally and Goin-Débé. These originally contiguous forests, are now separated by a land portion of 15 to 30 km width, which consists of a mosaic of forest fragments, cultivation fields, fallows and coffee, cacao and hevea plantation. Southwestern Ivory Coast, and especially Taï National Park has been the subject of much research (MANGENOT, 1955; AUBREVILLE, 1957, 1958; GUILLAUMET, 1967; GUILLAUMET & ADJANOHOUN, 1971; AKÉ ASSI, 1984, 2001, 2002; De ROUW, 1991; CHATELAIN & al., 1996, 2010). All these studies have provided much information on the floristic richness of this area and its uniqueness compared to other Ivorian forests, including the presence of many narrow endemic species called "Sassandriennes species" (MANGENOT, 1955).

Considering the floristic importance of this study area and the increasing human pressure and the loss of species which could result from this, it is important to address the impact of forest fragmentation and destruction on the floristic composition and diversity through sound scientific results so that political authorities can take appropriate action. In this contribution we make a comparative study of the floristic diversity between fragments and continuous forest.

In this contribution we will compare forest samples conducted in forest fragments and in continuous forests in terms of species richness and diversity, family richness and dominance, global floristic composition and dominance of life forms and ecological strategies.

Material and methods

The study area

The study area is located in the Guiglo region at the South west of Ivory Coast (Fig. 1). The area is circumscribed by the continuous forests of Taï National Park to the East, Cavally and Goind-Débé classified forests to the East, Paulé-Oula village to the South and Zagné village to the North. The main activity in this region is agriculture. The area is situated between 5°45' and 6°35' North and between 7° 13' and 8°00' West. The region experiences a subequatorial climate (ELDIN, 1971) with a major rainy season from February to November. The monthly mean temperature spans between 24.5° and 26.7° and the annual precipitation changes from 1700 mm in the North to 2000 mm in the South. Laterite soil on granite is widely dominant in the area (DE ROUW, 1991).

Vegetation consists of lowland evergreen rainforest which is characterized by the association of *Eremospatha macrocarpa* (G. Mann & H. Wendl.) H.Wendl. and *Diospyros mannii* Hiern. Those forests is home of many narrow endemic "Sassandriennes" species (GUILLAUMET, 1967).

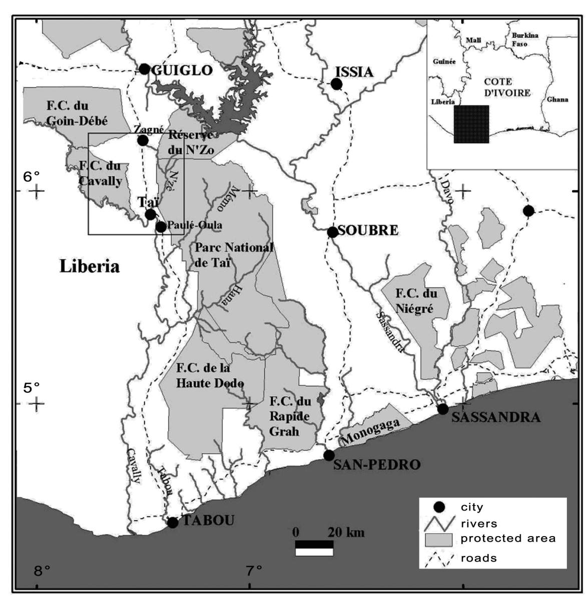

Fig. 1. – Map of southwestern of Côte d'Ivoire showing the study area by the square.

Data sampling and analysis

Sixty-four forest fragments have been sampled. All were located in similar topographic position (upper part of the slope). Twenty-one further samples performed in continuous forests (also upper slope) have been used for comparison. Detailed floristic analyses of these samples have been published elsewhere (Continuous forest: Bakayoko & al., 2004; Forest fragments Bakayoko & al., in press).

Sampling has been made following Gautier & al. (1994) linear method which has been widely used for floristic and structural studies of tropical forests in Africa and Madagascar (Bakayoko, 1999, 2005; Chatelain, 1996; Kouamé & al., 1998; Messmer & al., 2000; Bakayoko & al., 2004). This method consists in a 200 m long linear sample. All contacts of the vegetation with vertical lines placed at intervals of 2 m along the transect are recorded with species identification and height of the contact.

In forests fragments, the transect is placed lengthwise in order to have maximum length of sample. In order to eliminate edge effect, we excluded 10 to 15 m from the boundaries. As a consequence, in small fragments transect length is sometimes less than 200 m. For each fragment, we established only one transect whatever its size. Total sampling length amounted to 9400 m in fragments and 4400 m in continuous forests.

Species were identified in the field with the flora of Hawthorne (1996) and Kasparek (2000). All species identifications have further been checked in the herbarium of CSRS (Swiss Center of Research in Ivory Coast) and in the Geneva herbarium. Reference fertile material has been deposited in these herbaria. All taxonomic citation in this study are based on the African Plant Database (African Plants Database, 2011).

The diversity of continuous forest and fragments have been compared through the Shannon index (Shannon, 1948), the Evenness index of Pielou (1966) and the accumulation curve of the species, which interpretation is similar to the classical species-area curve. Diversity has further been analyzed first by separating the species according to their families and then by attributing each species to one out of ten life forms following Aké Assi (2001, 2002), and to one out of three ecological strategies following Hawthorne (1996) and additional field observations. These comparisons have been performed using either species richness of a category, or density. Density as understood in this contribution is the percentage of sampling points at which a species has been recorded.

Results

Floristic richness and diversity

The total flora sampled in the study amounts to 749 plant species belonging to 414 genera and 99 families. Irrespective of fragments or continuous forest, the dominant species were undergrowth taxa such as *Diospyros soubreana, Napoleonaea vogelii, Diospyros mannii* and lianas such as *Neuropeltis acuminata, Tiliacora dinklagei, Manniophyton fulvum, Agelaea pentagyna* and *Connarus africanus* (cited in decreasing order of density). From these species, only *Neuropeltis acuminata* is really abundant in both continuous forests and fragments.

Among them, there are 45 narrow endemic Sassandriennes species (following Guillaumet, 1967), the most abundant being: *Androsiphonia adenostegia, Chidlowia sanguinea, Chrysophyllum taiense, Calpocalyx aubrevillei, Didelotia idae, Warneckea golaensis, Trichoscypha cavalliensis* and *Whitfieldia colorata.* Most of them have been recorded throughout the study area, with the notable exception of *Didelotia idea* which has only been found in the North-West. Forty-two Sassandriennes species have been observed in fragments compared with 35 in continuous forests. However, we have to take into account the different sampling size in the two habitats, with a total of 4700 sampling points (i.e. 9400 m of transects) in fragments whereas the sampling size in continuous forest was only 2200 points (4400 m).

In total, 372 species have been recorded in both fragments and continuous forests. The 129 species that have been found in continuous forest only are mainly primary or secondary species (40% each) and to a lesser extent pioneer species (20%), whereas the 248 species found only in fragments are more or less evenly represented in the 3 ecological categories (38; 33; 29% respectively).

Table 1. – Comparison between fragments and continuous forests diversity through Shannon-Wiener and Pielou Evenness indexes.

Index	Continuous forests	Forest fragments	Probability
	n = 21	*n* = 64	Z test
Shannon	4.08	4.2	**
Pielou evenness	0.86	0.9	***

Results of the comparison between continuous forest and fragments are summarized in Table 1. Forests fragments have higher diversity and species evenness than continuous forest. Analysis of accumulation curves of the species (Fig. 2) shows higher richness of fragments up to 2700 m of transect. Beyond that point, continuous forest richness becomes higher than that of forests fragments. The slope of the accumulation curves at their maximum value (beyond the 4400 m for the continuous forest and 9400 m for the fragments) shows the high floristic richness of the study area.

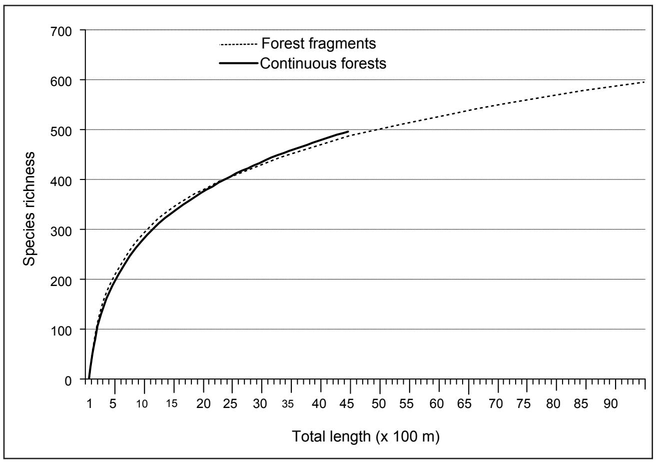

Fig. 2. – Species accumulation curves along transects in forest fragment and continuous forests. Results of 100 random permutations in the sequence of sampling points.

Families richness and dominance

Most dominant families in the area are represented both in continuous forests and fragments. These dominant families include *Annonaceae*, *Apocynaceae*, *Euphorbiaceae*, *Caesalpiniaceae* and *Rubiaceae*. Some minor families with less than three species have been recorded either in fragments *(Anisophyllaceae, Araliaceae, Aristolochiaceae* and *Athyriaceae)* or in continuous forests *(Adiantaceae, Amaryllidaceae, Boraginaceae, Polypodiaceae, Rapateaceae, Selaginellaceae).* In the following analysis, we will limit our comparison to the dominant families.

For these dominant families we have found no significant difference in species richness between continuous forests and fragments according to the Student test. In contrast, if we now consider family density (Table 2), we observe a significant difference for all families except *Hippocrateaceae* and *Marantaceae*. Families with higher density in continuous forest are *Anacardiaceae*, *Annonaceae*, *Chrysobalanaceae*, *Ebenaceae*, *Melastomataceae* and *Rubiaceae*. Families with higher density in fragments include *Apocynaceae*, *Araceae*, *Convolvulaceae*, *Euphorbiaceae*, *Loganiaceae*, *Menispermaceae* and *Olacaceae*, which are mainly represented in the area by lianas, and other secondary species, but also *Caesalpiniaceae*, *Lecythidaceae* and *Sapotaceae* with mostly primary species.

Life forms and ecological strategies

We distributed species involved according to their life form and to their ecological strategy (primary, secondary and pioneer species) and compared them in terms of richness and density. We found no significant differences between continuous forests and fragments when species richness of categories (life forms as well as ecological strategies) was considered. We will thus present only the comparison based on the density of the species belonging to the categories.

Table 2. – Comparison of family density between fragments and continuous forests using the Z test.

Family	Continuous forests	Forest fragments	Probability
	n = 21	*n* = 64	Z test
Anacardiaceae	2.23	1.76	***
Annonaceae	6.25	4.11	***
Apocynaceae	4.33	5.15	***
Araceae	0.62	1.77	***
Caesalpiniaceae	15.92	17.87	***
Chrysobalanaceae	2.13	1.53	***
Connaraceae	2.37	2.24	*
Convolvulaceae	2.71	4.38	***
Ebenaceae	11.03	3.73	***
Euphorbiaceae	8.1	9.42	***
Hippocrateaceae	1.49	1.67	ns
Lecythidaceae	1.53	2.28	***
Loganiaceae	1.1	2.45	***
Marantaceae	1.47	1.52	ns
Melastomataceae	2.86	1.49	***
Menispermaceae	1.52	2.53	***
Olacaceae	4.13	4.24	***
Rubiaceae	6.81	4.33	***
Sapotaceae	0.88	1.89	***

The comparison of the density of the life forms is summarized in Table 3. Except for hemicryptophytes and microphanerophytes, density of life forms is significantly different between fragments and continuous forest. Chamaephytes, geophytes, megaphanerophytes, mesophanerophytes and nanophanerophytes have a higher density in continuous forest whereas lianas and the therophytes have a higher density in fragments.

Table 3. – Comparison of the density of life forms between continuous forests and fragments.

Life form	Continuous forests	Forest fragments	Probability
	n = 21	*n* = 64	Z test
Chamephytes	1.57	0.41	***
Epiphytes	0.49	0.39	**
Geophytes	0.81	0.41	***
Hemicryptophytes	0.39	0.33	ns
Lianas	20.7	28.17	***
Megaphanerophytes	9.08	6.79	***
Mesophanerophytes	31.17	28.5	***
Microphaneophytes	26.99	27.44	ns
Nanophanerophytes	8.8	7.44	***
Therophytes	0.01	0.11	**

Regarding ecological strategies (Table 4), the density of the primary, secondary and pioneers species are all significantly different. The pioneers and secondary species are more abundant in fragments whereas primary species have a higher density in continuous forests.

Table 4. – Comparison of the density of ecological strategies between continuous forests and fragments.

Ecological strategy	Continuous forests	Forest fragments	Probability
	$n = 21$	$n = 64$	Z test
Primary species	65.39	55.83	***
Secondary species	28.17	34.45	***
Pioneer species	6.43	9.71	***

Discussion

Raw figures for total flora as well as the distribution of local endemic Sassandrienne species seem to indicate a richer flora in fragments than in continuous forest. However, we have to take into account the different sampling size in the two habitats, with twice as much sampling points in fragments. Nevertheless, the comparison of Shannon-Wiener index and Evenness index showed a higher diversity and evenness in fragment transects compared with continuous forests transects.

Rudis (1995), Benitez-Malvido (1998), Laurance & al. (1998a, b), and Sizer & Tanner (1999) showed that fragmentation of forest induced an increase in secondary and even pioneer species (Tabarelli & al., 1999), consecutive to more disturbances and edge effects in fragments. Indeed our results demonstrate that density of pioneer and secondary species is higher in fragments. This incoming flora adds to the original flora of the isolated fragment and more than compensate for possible loss of primary species due to fragmentation and disturbance.

The analysis of the species accumulation curves when all samples of each habitat are considered together brings further insights to understand this apparent higher diversity of fragments: beyond 2700 m, the diversity in continuous forests becomes higher than in fragments. The accumulation of new secondary or pioneer species in fragments becomes increasingly rare with the increase of sampling size, because the secondary and pioneer flora that can potentially invade fragments is much less diverse. In continuous forests which are less disturbed, the cumulated species number continues to grow with increase in sampling size due to the continuous accumulation of rare primary species. However, species recorded in fragments only are not restricted to secondary or pioneer species and species recorded only in continuous forests are not all primary species.

As for diversity across families, the higher density in fragments of liana-rich families such as *Connaraceae*, *Hippocrateaceae*, *Convolvulaceae*; or secondary species-rich families like *Euphorbiaceae* can also be explained by the effect of disturbance (Laurance & al., 1991; Alvira & al., 2004; Zhu & al., 2004). In turn, families rich in primary species such as *Rubiaceae*, *Annonaceae* and *Ebenaceae* are more dominant in continuous frorest (Taberelli & al., 1999; Zhu & al., 2004).

Regarding life forms, woody plants (trees, shrubs and lianas) widely dominate both continuous forests and fragments. Fragmentation does not dramatically change the morphological spectrum of forests. However, density of trees and shrubs is significantly lower in fragments, (with the exception of microphanerophytes which show a non-significant increase), whereas liana density increases significantly. Similar observations were made in China between a primary forest and fragments (Zhu & al., 2004). Fragments forests by their disturbances, are favourable for the lianas species proliferation (Laurance, 1991; Kouame, 1998).

In terms of ecological strategies, continuous forests are dominated up to 2/3 by primary species. In our study area, continuous forests have a protection status. Consecutively, they experience less disturbances than fragments and offer better conditions for the survival of primary species. Following fragmentation, density of secondary and pioneer species increase significantly, and primary species drop to slightly more than ½ of the total density. Fragmentation has been demonstrated to increase edge effect (Laurance & al., 1998a), and specifically to increase effect of wind and direct sunshine (Saunders & al., 1991), and lower humidity (Lovejoy & al., 1986), promoting pioneers and secondary species regeneration and their development (Alexandre, 1982; Swaine & Hall, 1983; Zuidema & al., 1996; Laurance & al., 1998b). In our study, pioneers species were generally observed either close to forest edge or in forest gaps, i.e. in situations where effect of the wind and direct sunshine is stronger.

Impact of isolation and further direct human disturbances on forest fragments involves an increase of secondary and pioneers strategies and liana life forms. However, resilience of a high proportion of primary species, including Sassandriennes endemics, in fragments demonstrate that promoting their conservation in southwestern Ivory Coast can substantially contribute to general conservation of plant species.

Acknowledgements

The project on forest fragmentation in South Western Ivory Coast was funded by the Fond National Suisse de Recherche Scientifique (subside n° 31-59469.99, projet «Fragmentation forestière dans le Sud-Ouest de la Côte d'Ivoire») and has been conducted through the Swiss Center of Scientific Research in Ivory Coast. The project also benefitted from the technical support of the Conservatoire et Jardin botaniques de la Ville de Genève (CJB) and the laboratory of Botany of the University of Cocody. We thank the directors of these institutions and all the people who contributed to the success of this work.

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