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FLORISTIC CHARACTERISTICS OF THE MOSAIC AND HOW FOREST PROGRESS ON SAVANNA IN THE LAMTO RESERVE REGION (CÔTE D'IVOIRE)?

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ABSTRACT

A large band of forest-savanna mosaic extends between the Sudanian (dry) and Guinean (humid) regions in West Africa and undergoes bush fires, agriculture and logging, in the central parts of Côte d'Ivoire, especially in the Lam to Reserve region. Former studies showed a remarkable degree of vegetation dynamics in this region with forests advancing against savanna. However, the floristic components of the mosaic and the relevant tree species involved in the regeneration dynamics were not identified. Vegetational data were recorded along eight forest-savanna transects by distinguishing segments inside or close to the border zone for each type of vegetation. Our results showed a continuous floristic variability between forest and savanna but a real distinction between floristic compositions of transects segments. Six pioneer tree species like *Trichilia prieureana*, *Erythroxylum emarginatum*, *Holarrhena floribunda* were identified as responsible of the forest progress on savanna in the Lam to Reserve region. This regeneration was realized in a broad transition belt of 60 m in length between forest and savanna. These results allow making a warned choice of the know more about the conditions of forest regeneration in the forest-savanna mosaics.

INTRODUCTION

Both in the Guinean and the Sudanian regions of Africa, a mosaic of forests surrounded by savanna covers large parts of the landscape (White, 1983). Its rich biodiversity is an important natural resource for food, medicine, timber and firewood for local inhabitants **(**Guillaumet and Adjanohoun, 1971**;** Bellefontaine *et al.*, 1997). Nowadays, bush fires, agriculture and logging are the main causes of a general decrease in biodiversity in the forest-savanna mosaic in the central part of Côte d'Ivoire, especially in the Lam to Reserve region (Aubréville, 1947; Adjanohoun, 1964; Guillaumet and Adjanohoun, 1971) see Fig. 1.

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In this region, forests are described as formations in various stages of reconstitution and the specific diversity is high in the first stages of reconstitution (Devineau, 1984). Using aerial photographs of forest-savanna edges, Dugerdil, (1970), Spichiger (1975) and Gautier (1990) showed that, despite of annual burning, the forests advance against savanna in Central Côte d'Ivoire by 0.5%. Floristic components of the mosaic and the regeneration dynamics in term of species involved in the progress of the forest on savanna were not considered. In thecontext of Climate Change and its consequences on vegetation (Amon *et al.*, 2015, Angoni *et al*., 2015) it is important to know the characteristics of the mosaics and the conditions of their regeneration. Vegetational data were recorded along eight forest-savanna transects in the region of the reserve.

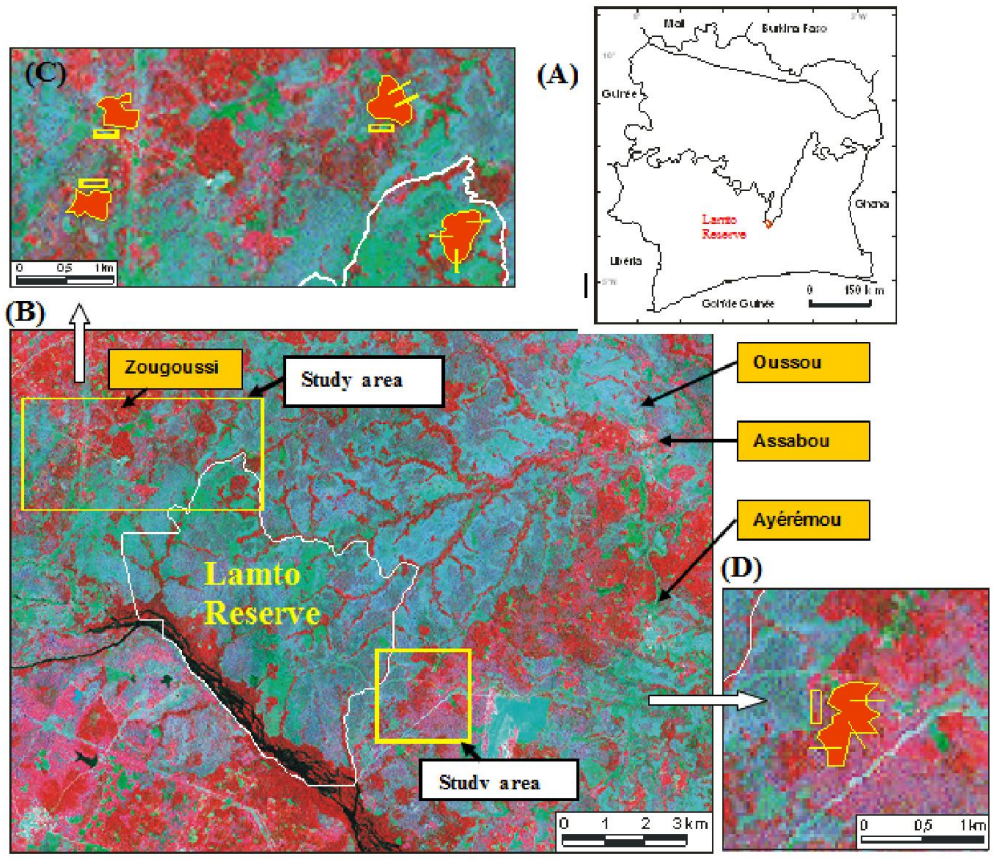

Figure 1. Transects location in the Lamto Reserve region. (A) Location of the Lamto Reserve in Côte d'Ivoire ; (B) Location of the study site ; (C) plots arrangement in the North-West of the Reserve with 5 transects represented by yellow lines ; (D) plots arrangement in the East of the Reserve with transects represented by 3 yellow lines. In red: forest and gallery; in green and blue: savanna; in pink: utilized areas. Landsat Image from 13 April 2000, ETM+

Our objectives were (1) to detect the floristic characteristics of the mosaic and (2) to identify the species involved in the progress of forest.

MATERIALS AND METHODS

Study site

The forests of the Lamto Reserve region are different types of dense humid semi-deciduous forests, characterized by *Triplochitetalia* and *Celtidetalia* species (Guillaumet and Adjanohoun, 1971) in different stages of secondary succession (Devineau, 1984). The savanna is characterized by the *Loudetia simplex* association (Adjanohoun, 1964) and stands of the palm *Borassus aethiopum*. The annual average of rainfall is 1 176 mm (1983-2003) and the mean annual temperature is 26, 7°C (Avenard, 1971). Related to the geomorphology, the distribution of the ferruginous soil types can be summarized as follows: on the top and on hill slopes, soils are profound and gravelly while in the lower part, they are fine and hydromorphic (Avenard, 1971; Perraud, 1971). The Lamto Reserve covers an area of 2 500 ha located in the central part of Côte d'Ivoire (Fig. 1), which has been protected against human activities since 1961. Outside of the Reserve, forests are under human activities and reducing in fragments. Our study was carried out at 6°14'-15'N and 4°06'-5°03 W.

Sampling

Three forest locations were chosen (Fig. 1). One forest was located inside the Reserve and the two others were outside, representing undisturbed sites without agricultural activities. These forest fragments are in the ownership of the inhabitants of the villages of Zougoussi and Ayérémou. At each forest site, three replicates of forest-savanna transects were placed, except for the smallest forest at Zougoussi where we placed two. To measure the dynamics in the transition zone, of forest and savanna, continuous transects continuous transects were established from the forest interior to the savanna (see Fig. 2).

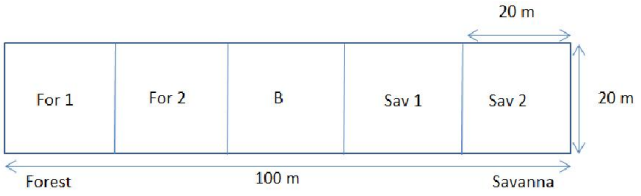

Figure 2. Detail of continuous transect. For=Forest; Sav=Savanna and B=Border, Position (1) or (2) along transect

A distinct zonation between forest interior, border and savanna was made by dividing transects into five corresponding plots of 400 m^2 each. The species names, total height and diameter (d.b.h.) of tree individuals taller than 2 m were recorded. In addition, environmental parameters like cover of grass litter, total litter, fire (burned surface), Termites' nest, and vegetation

were estimated, according to the decimal scale of Londo (Dierschke, 1994) and also density, species number and biomass in each plot. The names of taxa refer to Lebrun and Stork (1991-1992, 1995, 1997).

Data analysis

The floral analysis which reports more efficiently similarities of environmental conditions in this region (Devineau, 1984) was used to detect the changes along transects. To distinguish the floristic composition of the tree community between forest locations we calculated the degree of similarity of all plots by cluster based binary data (Piélou, 1972) correlated with the similarity index of Czekanowski-Dice-Sorensen named *Ics*. The index *Ics* is known to be the only one being linearly related to a "measure of absolute similarity" and had been strongly recommended (Wolda, 1981; Hubaleck, 1982; Smith and Goodman, 1986; Magurran, 1988). Then to take out the characteristics of the mosaic, we use a Principal Components Analysis (Hill and Gauch, 1980). The samples which remained close together indicate their similarity. Concerning the regeneration dynamics, the distribution of juvenile plants (< 5cm dbh) along transects was mapped. Variation of environmental parameters and its relation to species regeneration in term of juvenile plants number of the most dominant species was determined with a regression analysis.

RESULTS

Floristic characteristics

The dissimilarity between forests and savanna and between transect segments were visible. The cluster analyses revealed, at the first level, a strong dissimilarity (80%) between savanna and forest (Fig. 3). Then, forests clustered at 35% in two groups. One group was represented by the Ayérémou location (dissimilarity around 70%) and the other group by Zougoussi and Lamto locations. These latter forests were associated at 60%. The first and second axis of the PCA (Fig. 4) explained 26.2% of the floristic variability of the data sets (Table 1).

There were 5 units of beta diversity along the most dominant gradient which means a clear distinction between savanna and forest. Overall, the variation in the floristic composition was continuous and kept a well distinction also between transect segments. The second axis showed a separation of the floristic components in three groups. The first group (1) was composed by all segments of one forest (Ayérémou).The second group (2) contained all forest (For 1, For 2) and border segments (B) of the two other forests (Zougoussi and Lamto). The third one (3) is composed by all savanna segments (Sav 1, Sav 2) whichremained floristically similar in all sites.

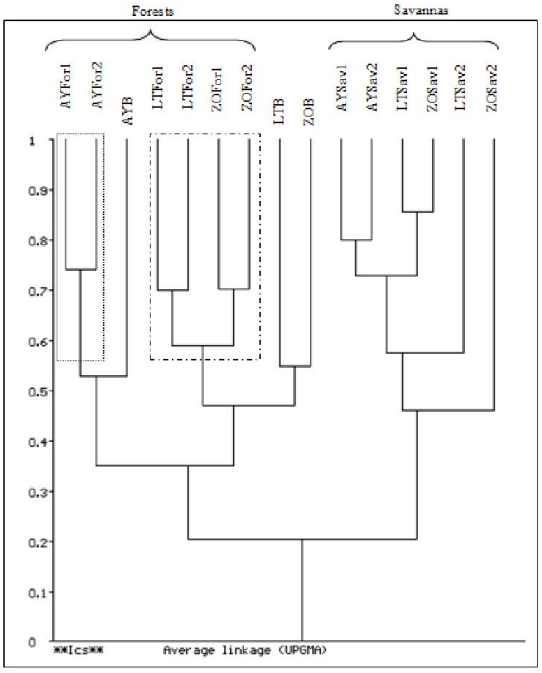

Figure 3. Cluster based on the incidence (presence/absence) of species. AY: Ayérémou; LT :Lamto and ZO : Zougoussi. For: forest; B: Border and Sav: savanna. The numbers indicate the position along forest-savanna transect. From the interior of forest or savanna (1) to the border zone (2)

Table 1. Summary of PCA based on presence/absence of species in the plots. X1-X2: axis of PCA

	X1	X2	X3	X4	Total inertia
Value of axis	0.776	0.407	0.170	0.121	4.511
Lengths of gradient	4.696	2.769	2.355	1.860	
Cumulatives values of floristic variability (%)	17.2	26.2	30.0	32.7	
Floristic variability (%)	17.2	9.0	3.8	2.7	

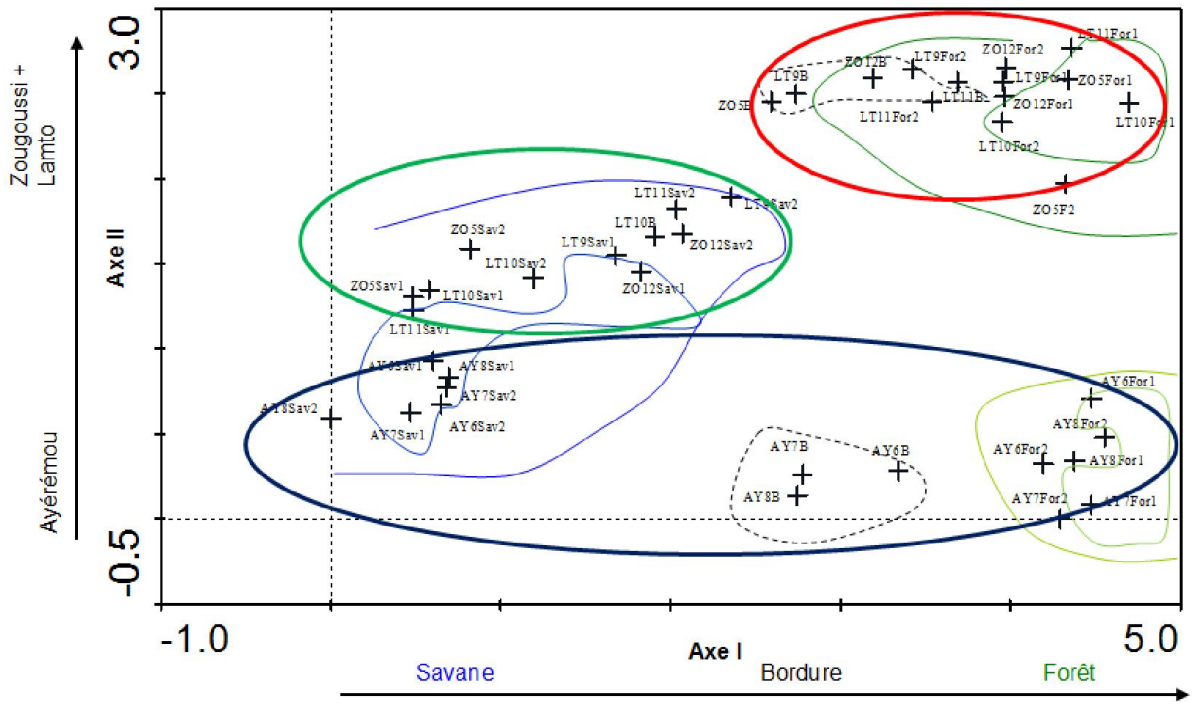

Figure 4.a) Percent similarity between forest locations and transect segments. Average linkage (UPGMA) was used with the Czekanowski-Dice-Sorensen for all sample species. b) Principal components based on incidence (presence / absence) of species along forest-savanna transect. AY: Ayérémou; ZO: Zougoussi and LT: Lamto. Number of transects from 5 to 12. For: Forest; B: Border and Sav: Savanna. The other numbers indicate the position along transect, from the Interior of forest or savanna (1) to the border (2)

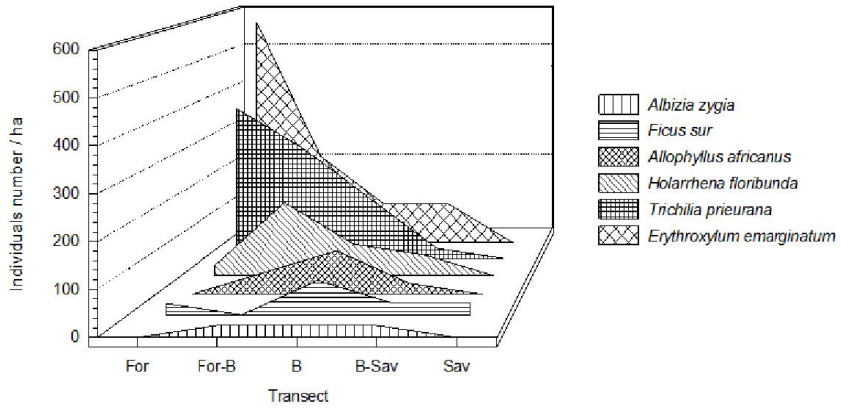

Figure 5. Distribution of juvenile plants of pioneer species along forest-savanna transects.
For: Forest interior; For-B: Forest Border; B: Border; B-Sav: Savanna Border and Sav: Savanna

Table 2. Regression analysis of the diameter class (<5cm) of the most dominant forest species and environmental parameters (n=40). Spearmans rank correlation coefficient; significant correlations (2-tailed, test wise error rate with bonferroni correction): *P<0.039;P<0.030;***P<0.001**

Species	Vegetation	Grasses	Fire
Dialium guineense	0.759***	-0.746***	-0.538***
Leucanodiscus cupanoides	0.753***	-0.761***	-0.554***
Trichilia prieurana	0.699***	-0.511**	-0.409**
Olax subscorpioidea	0.343*	-0.254	-0.189

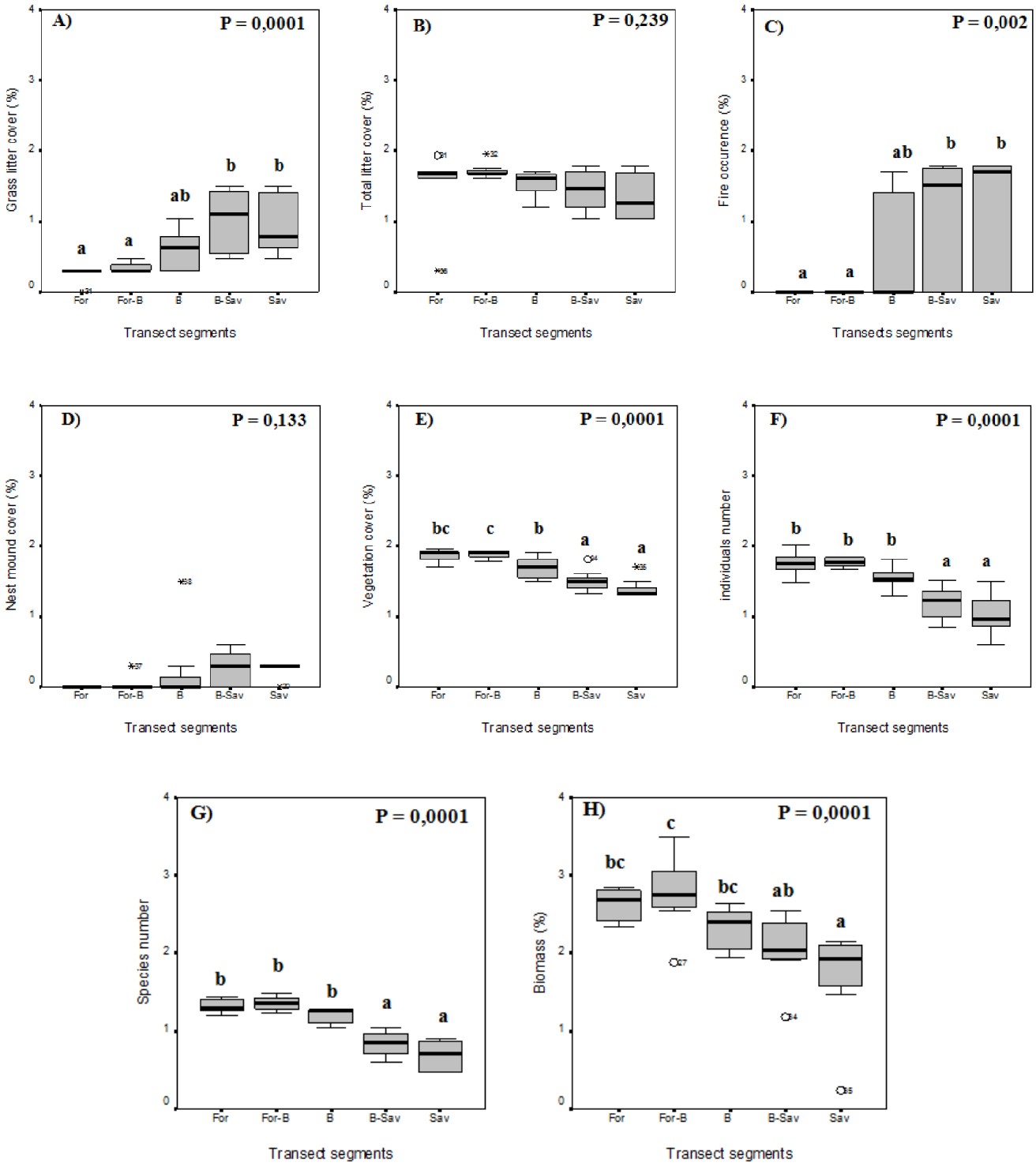

Figure 6. Box plots of floristic and structural parameters along forest-savanna transects in the Lamto Reserve region. A) Grass litter cover; B) Total litter cover; C) Fire occurrence; D) Termites nest cover; E) Vegetation cover; F) Density; G) Species number; H) Biomass from 40 plots. Statistical groups are indicated by letters (a, b, c). p = significance level

In all forests *Dialium guineense* and *Lecaniodiscuscupanioides* were dominant. In Ayérémou location typical species of semi-deciduous forest like *Triplochiton scleroxylon* was observed while species of secondary sites like *Ricinodendron heudelotii, Spondias mombin* and *Elaeisguineensis* were noted in Zougoussi location. Concerning the Lamto forest, certain species of savanna such as *Borassusaethiopum* and *Terminalias chimperi* were found. All border segments (B) were situated between forest and savannah.

The border segments at the Ayérémou location remained dissimilar to the other forest locations. Lamto and Zougoussi locations presented a strong similarity between their border segments (55%). However we noted that one border segment of Lamto (B) was in savanna's group. The savanna was clearly separated from forest locations. Species like *Borassusaethiopum*, *Bridelia ferruginea*, *Crossopteryx febrifuga*, *Terminalia glaucescens*, *Ficus sur* and *Cussonia barteri* were among the most frequent savanna species. The

savanna segments close to the border (Sav-B) did not contain only typical savanna species but some forest species such as *Holarrhena floribunda* and *Erythroxylum emarginatum* could be found there.

Forest-savanna dynamics and pioneer species

Among the 99 tree species noted along the forest-savanna transects 37 were present with juvenile plants (< 5 cm d.b.h.). Only six of them distributed their juvenile plants beyond the border zone between the forest and the savanna along transects (Fig. 5). These were *Trichilia prieureana*, *Erythroxylumemarginatum*, *Holarrhena floribunda*, *Allophylus africanus*, *Albizia zygia* and *Ficus sur*. For *T. prieureana* and *E. emarginatum* most juveniles were recorded in the forest interior (For) and their numbers decreased towards the savanna. The highest number of juvenile plants of *H. floribunda*, *A. africanus*, *A. zygia* and *F. sur* was found at the forest border (For-B) and declined both towards the interior of the forest and the savanna.

Concerning environmental parameters, no significant difference was between forest locations. The difference was observed between transects segments concerning grass litter cover, fire occurrence, vegetation cover, density, species number and biomass (Fig 6). Grass litter cover and fire occurrence increase from the forest towards the savanna whereas total litter cover remains the same along transect. Vegetation cover, individual number, species number and biomass were also raised in forest and decrease gradually towards the savanna. In reference to the values of parameters, transect segments were separated in two parts in respect to statistical groups: forest segment (contain border segment) and savanna segment.

A regression analysis of the frequent and most dominant species in terms of juvenile plants number revealed that there was a strong positive correlation between the forest species *Dialium guineense*, *Leucanodiscus cupanoides* and *Trichiliaprieurana* with the vegetation cover (Table 2). They were negatively correlated with grass litter and fire occurrence. *Olax subscorpioidea*, the most dominant species, showed only a weak correlation with vegetation cover and did not show a significant correlation with grass cover and fire occurrence. The savanna border segment contained pioneer forest species like *H .floribunda* and *E. Emarginatum* where as the percentage of pioneer forest species was high indicating forest encroachment towards the savanna. A broad transition belt of 60 m in length was identified between forest and savanna and could be defined as a regeneration dynamic zone in the mosaic. This observation could be made on all transects.

DISCUSSION

Floristic characteristics

The floristic composition in the protected area was not significantly different to the utilized area. The floristic composition changed clearly and continuously with a zonation along forest-savanna transects but the separation of the forests in two groups could reveal that these forests were different. Devineau (1984) assert that the evolution of the diversity which is not linear in the first stages of reconstruction process could characterize the zonal formations.

However, Ayérémou location contained alone the most characteristic species of semi-deciduous forests, whereas species of the secondary formations and savanna species mostly occurred in the other forests. The forest of Ayérémou location was possibly less disturbed by human activities what results in its floristic and structural distinctiveness (Koulibaly *et al.*, 2010). The forest in the Lamto Reserve which was under human pressure would remain in a young stage of secondary succession even after 50 years of protection. The savanna border segments (Sav-B) were floristically close to the typical border segments (B) in Zougoussi and Lamto locations because of the high density of small forest trees like *R. Holarhena floribunda*, *Erythroxylum emarginatum*, *Trichiliaprieureana* and *Allophylus africanus* which were distributed on a large band between forest and savanna. This expresses the dynamic between adjacent formations by enlargement of the forest species distribution area. In general, savannas in our studied sites showed a floristic composition in accordance with previous works in the region (Roland and Heydacker, 1963; Vuattoux, 1970; Menaut, 1971; Hiernaux, 1975). Remarkably, regeneration by juvenile plants in the savanna plots was only by forest tree species what indicates an encroachment of forest against savanna.

Forest-savanna dynamics and pioneer species

Forest progresses by a swarming at long distance of the forest species pioneers (Spichiger, 1975). We identified six species which colonized the border zone (B) between forest and savannah, and the savanna segments (Sav-B) which obviously initiate the succession towards forest. Some of the species like *Anogeissus leiocarpus, Ficus exasperata* and *Lonchocarpus sericeu* play a similar functional role concerning the forest-savanna dynamics in neighbouring countries (Nansen *et al.*, 2001**).** The floristic and structural parameters values (cover of grass litter, fire occurrence, vegetation cover, density, species number and biomass) were similar between forest sites.The capacity of pioneer tree species to become established beyond the border zone depended on the vegetation cover and absence of fire. *Olax subscorpioidea*, the most dominant species, seemed to be well adapted to vegetation cover, grass cover and fire occurrence. This species is often well represented in dry dense forest and dense woodland (Dourma *et al.*, 2012) and can colonize acid soils **(**Tohngodo *et al.*, 2009). However, it becomes rare under human activities **(**Ogunleye *et al.*, 2004**,** Ihenyen, *et al.*, 2010**)** and the most vulnerable species due to fruit exploitation in Cameroun **(**Dibong *et al.*, 2011**)**.This situation was not known in Lam to Reserve region.

The presence of adult individuals of savanna species such as *Borassus aethiopum* and *Terminalia schimperi* in the forests of the Lamto Reserve region testify the savanna state in the past of this forest Devineau (1976). The implementation of forest by forest species inside wet savannas was discussed (Favier *et al.*, 2004; Gignoux *et al.*, 2006) in regards to savannas characteristics (Abbadie *et al*., 2006) and was observed in the PNC on old dead termites' nests (Roth *et al.*, 1979; Mühlenberg, 1990). Fairhead and Leach (1998) demonstrated that new forests have been established inside savannas, since 200 years in the northern part of the Guineo-Congolese zone of Côte d'Ivoire and semi-deciduous forests in the West Center Ghana by the colonization of old surfaces.

In our study the separation of transect segments at the species level and also concerning several floristic and structural parameters allowed us to distinguish a particular zone where pioneer species realized the vegetation dynamics. Typically there was a broad (c. 60m in length) transition belt was identified and could be defined between forest and savanna as a regeneration dynamic zone of the mosaic in the forest-savanna of Lamto Reserve region. The studies of the forest-savanna borders were often realized to determine border effects to protect the central part of the forest and allow its reconstitution (Van der Maarel, 1990, Kent *et al.* 1997, Fagan *et al.* 2003). In Côte d'Ivoire, Hennenberg (2005) showed a border effect in the forest-savanna mosaic of PNC where the ecological parameters varied consequently with *Anogeissusleiocarpus* as a pioneer species on maximum 55 m of length. These distances of regeneration zone in two regions Comoé and Lamto are closed. This situation allows us to initiate detailed study of follow-up of pioneer species regeneration on around 60 m of length in the transition zone of forest-savanna mosaics.

Conclusion

Forests are more or less disturbed and exist as fragments of different sizes due to rapid exploitation in the forest-savanna mosaic of Lam to Reserve region. The floristic characteristics reveal two types of forests in the Lamto Reserve Region. These forests occur in different successional states from less disturbed (Ayérémou) to considerably disturbed (Lamto, Zougoussi). The protection area of Lamto reserve could be enlarging to take account of the richness of the forest of Ayérémou. The relevant tree species involved in the regeneration dynamics are now identified. These pioneer species which initiate the encroachment of forest towards savanna on a typically broad zone of 60 m of length have to be considered in a management process of the forest-savanna mosaic. Our study providing detailed data on forest-savanna floristic and dynamics in the mosaic and recommend further studies on the impact of environmental parameters variations on the development of pioneer species.

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