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BEETLES ABUNDANCE AND DIVERSITY IN RELATION WITH PLANT DIVERSITY IN BANCO NATIONAL PARK AND HUMAN DISTURBED AREAS AROUND

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ABSTRACT

The aim of this work is to study the correlation between plant diversity and beetles populations in Banco National Park and Human modified areas around. Thus, Beetles and flora inventory has been made in the forest and Human modified areas. The floristic inventory required two sampling methods: roving survey method and surface survey method. For beetles capturing, yellow ground trap, yellow height trap, pitfall trap and screen trap were used. A total number of 155 plant species divided into 136 genera belonging to 50 families were inventoried. In forest area, 71 plant species divided into 65 genera belonging to 32 families were inventoried. In Human modified areas, 84 plant species divided into 71 genera belonging to 27 families were inventoried. A total of 8443 betles individuals divided into 53 families were captured. Beetles are more abundant in Human modified areas but more diversified in forest. Correlation between plant diversity and beetles community showed that diversity of plant species has a positive effect, on beetles abundance and family richness in forest area. This is not the case in Human modified areas. The diversity of plant species contributes to the increase of beetles abundance and diversity in a habitat. However, Human disturbance can break this link.

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INTRODUCTION

For centuries, human activities have contributed to natural habitats destruction and fragmentation, particularly for agriculture, construction of road and urbanization (Hervé, 2010). The integrity and extent of natural habitats are decreasing, fragmentation and degradation of forests are continuing, endangered species are considering as at risk categories, abundance of vertebrate and invertebrate species is suffering depleting (Villemey, 2015). In the same case, the Banco National Park, because of its originality, both botanical and zoological, is subjected to an increasingly visible imbalance due to human actions such as hunting, agriculture, construction of road and urbanization. Since its classification as a National Park, its vegetation continues to decline on its margins, wood species such as, *Terminania ivorensis* (Combretaceae), *Turraeanthus africanus* (Meliaceae), *Tarrieta utilis* (Malvaceae) have become very rare (Béligné, 1994). However, one of the factors on which the diversity and abundance of arthropod species depend in an environment at different spatial and temporal scales is the vegetation characterized by its structure, composition and dynamics (Hervé, 2010). In such a context, it is essential to know if, the abundance and the diversity of beetles in Banco National Park escape sufficiently the risk of disappearance linked to the deforestation, because the annihilation of a species can disturb the entire living system since with it disappears an unknown quantity of interactions with other species and their environment (Boucher et Fontaine 2010). However, this question is far from being answered because the links between insect communities and plant communities are very rarely studied by entomologists in Côte d'Ivoire.

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Such a study has never been carried out in Banco National Park. In order to highlight the importance of plant diversity for beetle populations within the Banco National Park, the objective of this work is to study the beetles abundance and diversity in relation with plant diversity in Banco National Park and Human modified areas at its periphery.

MATERIALS AND METHODS

Materials: The study material consists of a stereo microscoop (BYO ST-11) of magnification 40 for insects observation, identification keys which are those of (Delvare et Aberlenc, 1989, Leraut, 2003), a GPS device (Global Positioning System) (Garmin 60 CSx) to find geographic coordinates, altitude, plot routes and mark different sites, yellow traps, pitfall traps and screen traps for beetles capture, containers containing 70 % alcohol for the conservation of beetles.

Methods

Study area: The study carried out in Banco National Park (Côte d'Ivoire) and its periphery areas. Banco National Park covers an area of 3474 hectares and is encircled by the agglomeration of Abidjan. It extends between 5 ° 21' and 5 ° 25' north latitude and 4 ° 01' and 4 ° 05' west longitude (Figure 1). It's climate is subequatorial with four seasons. The average annual precipitation, recorded by the SODEXAM meteorological exploitation for the period from 2006 to 2016, is 1733 mm. The average temperature is 27.2 °C with an amplitude of 4.3 °C. It is around this Park that 4 sites, which are Autoroute, Gare, Sagbe and Filtisac were chosen according to different types of human activities. Each of these four sites is made up of two parts: the first one, which is the Human modified area located at the periphery of the forest and juxtaposed with the second part which is the forest area located more inside the forest. This second part is undisturbed. It is in these sites that the sampling of Beetles and plants inventory were done.

Methods of floristic inventory: Floristic inventory required the use of two sampling methods, namely the roving survey method and the surface survey method. The roving survey is a botanical survey method that has been used by many researchers, including Aké Assi (1984); Kouadio (2000) et Kouassi (2007). It consists to go through the plot in all directions, noting the species of plants encountered. In the case of this study, it consisted of following the transects traced. It allowed to inventory the different plant species present. A total of 32 surface surveys, 16 in the Human modified area and 16 in the forest zone, were carried out. The surveys took into account all the plant species present in the plots. The surface survey consisted to delimit plots of 100 m^2 (10m x 10m) in the study sites. In each plot, phytosociological surveys were carried out according to the classic stigmatism method of Braun-Blanquet (1932). This method is based on floristic homogeneity principle of the studied surface. For each inventoried species, a coefficient of abundance-dominance is assigned to it. This coefficient corresponds to the expression of the relative space occupied by all the individuals of this species.

Methods of beetles capture: Yellow ground trap, yellow height trap, pitfall traps and screen traps were used for catching beetles. Four transects of 100 m, spaced from 20 m were traced. On each transect, five yellow traps were placed on the ground at intervals of 25 m. At 1 m from each yellow trap was placed a pitfall trap. These traps were set randomly. Three yellow height traps, were placed randomly on transects 1, 2 and 4. The yellow height traps were placed at 0.5 m, 1 m and 2 m from the ground. Three screen traps were placed through the Human modified area and the forest. A total number of 46 traps were used. Twenty yellow ground traps, 20 pitfall traps, 3 yellow height traps and 3 screen traps. The same device was used in Human modified areas as in forest for the 4 sites. Beetles sampling was conducted from November 2015 to October 2016 due to one sampling per month. Beetles collected were identified at the family level.

Statistical Analyses: Past 3.11 software was used for statistical analysis. The abundance comparison was done by the Anova and Tukey's tests when the Levene test shows that the distribution is homogeneous. When the Levene test indicates that the distribution is not homogeneous, non parametric tests were done using Fridman tests, for more than two samples and Wilcoxon for two samples. The correlation between floristic diversity, abundance and diversity of Coleoptera was established using statisticat version 7.1.

RESULTS

Floristic composition and diversity evaluation

Floristic composition: A total of 155 plant species shared out into 136 genera belonging to 50 families, including 27 families identified in the Human modified areas and 32 families in the forest. In the Human modified areas, the dominant families are Poaceae, Euphorbiaceae, compositeae, Rubiaceae, Leguminoseae, Cyperaceae, Malvaceae and Convolvulaceae. In the forest zone, Leguminoseae, Araceae, Apocynaceae, Rubiaceae, Malvaceae, Dichapelataceae and Connaraceae are more represented in species number. The floristic composition comparison between the two zones shows that Euphorbiaceae, Cyperaceae, Leguminoseae, Rubiaceae, Apocynaceae, Malvaceae, Moraceae, Araceae, and Commelinaceae families are common to both areas. However, Leguminoseae, Apocynaceae and Araceae are more represented in the forest than in Human modified areas. Euphorbiaceae, Cyperaceae, Rubiaceae, Apocynaceae, Malvaceae and Moraceae are more represented in anthropized zone than in forest zone.

Floristic diversity

In forest area: A total of 71 plant species shared out into 65 genera belonging to 32 families were inventoried. The average floristic richness in forest varies from one site to another ($F = 6.449$; $p = 0.007$). Turkey's test distinguishes three groups. The first group representing low average richness consists of Filtisac and Autoroute sites. The second group representing high average richness consists of Gare site and the third group is the Sagbe site whose average floristic richness does not statistically differ from the two other sites. According to Shannon's index diversity average values, they are not differ statistically. However, equitability index vary statistically from one site to another ($X^2 = 8.9286$; $p = 0.03$) (Table 1).

In human modified area: In human disturbed area, 84 plant species shared out into 71 genera belonging to 27 families were inventoried. The average floristic richness in human disturbed areas varies from one site to another ($F = 10.07$; $p = 0.001$) (Table 2). Turkey's test distinguishes three groups.

Table 1. Floristic diversity and richness in forest

Index diversity	Filtisac	Gare	Autoroute	Sabgé	p
S	11.0 ±2.31^{b}	19.50±0.87^{a}	13.50±1.44^{b}	16.00±0.00^{ab}	0.007
H'	1.43 ± 0.13	1.36±0.03	1.24±0.22	1.08±0.21	0.698
E	0.61±0.00 ^{a}	0.46±0.00 ^{b}	0.47±0.07 ^{b}	0.39±0.08 ^{b}	0.030

All values are given as the mean ± standard errors and means with the same letter are not significantly different at the 5% level. (Tukey's test). S : family richness, H' : Shannon index, E : equitability index

Table 2. Floristic diversity and richness in human modified area

Index diversity	Gare	Sabge	Autoroute	Filtisac	p
S	11.50±2.18^{ab}	17.00±1.58^{a}	5.75±0.85^{b}	6.25±1.18^{b}	0.001
H'	1.76±0.14^{a}	1.43±0.04^{a}	1.21±0.11^{a}	0.94±0.35^{b}	0.035
E	0.73±0.01	0.51±0.03	0.44±0.04	0.47±0.16	0.076

All values are given as the mean ± standard errors and means with the same letter are not significantly different at the 5% level (Tukey's test). S: family richness, H': Shannon index, E : equitability index

Table 3. Beetles average abundance in disturbed and forest areas

Plots	Disturbed area	Forest area	p
Autoroute	88,75 ± 9,28 ^{aA}	66,33 ± 9,62 ^{bA}	0,004
Filtisac	78,91 ± 5,26 ^{aA}	53,66 ± 7,26 ^{bA}	0,002
Gare	120,58 ± 24,07 ^{aB}	115,5 ± 22,19 ^{bB}	0,04
Sagbé	83,5 ± 6,62 ^{aA}	96,33 ± 11,77 ^{bAB}	0,04

All values are given as the mean ± standard errors and means with the same small letter within the same site are not significantly different at the 5% level. All values are given as the mean ± standard errors and means with the same capital letter within the same area are not significantly different at the 5% level.

Table 4. Beetles diversity in Disturbed and forest areas

	Disturbed areas			*Forest areas*		
Index diversity	*S*	*H'*	*E*	*S*	*H'*	*E*
Autoroute	*23*	*2,11*	*0,36*	*32*	*2,85*	*0,54*
Filtisac	*25*	*2,21*	*0,36*	*29*	*2,75*	*0,54*
Gare	*30*	*2,59*	*0,44*	*37*	*2,98*	*0,53*
Sagbé	*32*	*2,54*	*0,39*	*32*	*2,74*	*0,48*

S : family richness, H' : Shannon index, E : equitability index

Table 5. Correlation between floristic richness, beetles abundance and families richness in forest area

	Beetles Abundance	Beetles families richness	Floristic richness
Beetles abundance	-	r = 0.89 p = 0.14	r = 0.986 p = 0.014
Beetles families richness	r = 0.895 p = 0.14	-	r = 0.955 p = 0.044

The first group representing low average richness consists of Autoroute and Filtisac sites. The second group representing high average richness consists of the Sagbe site and the third group is the Gare site whose average floristic richness does not statistically differ from the two other sites. According to Shannon's index diversity average values, they are statistically vary from one site to another (X^2 = 8.558 ; p = 0.035). But those of equitability index do not statistically vary (X^2 = 6.860; P = 0.076) (Table 2).

Beetles caught in general: In total, 8443 beetles belonging to 53 families were captured. The Gare site has the highest number of beetles (2833 individuals) with 33.56% of total catches. In Filtisac fewer beetles were recorded with 1591 individuals which represents 18.85% of all beetles caught (Figure 2).

Beetles abundance in human modified areas and forest areas: In human modified areas, beetles were more abundant at the Gare site with an average of 120.58 ± 24.07 individuals and less abundant at the Filtisac site with an average of 78.91 ± 5.26 individuals. Beetles abundance between different disturbed areas showed a significant difference (p = 0.03). Beetles abundance varies from one disturbed area to another (Table 3). In the forest, beetles were more abundant at the Gare site with an average of 115.5 ± 22.19 individuals and less abundant at Filtisac site with an average of 53.66 ± 7.26 individuals. A highly significant difference was observed between beetles abundance in the different forest areas ($p < 0.001$). Beetles abundance varies from one forest area to another (Table 3). The comparison of abundance between disturbed areas and forest shows that beetles are more abundant in disturbed areas than forest (Table 3).

Beetles diversity in disturbed areas and forest areas: In disturbed areas, more families were identified at Sagbé site (32 families) and fewer families at Autoroute site (23 families). However, Gare site has the highest Shannon diversity index

(2.59) and Autoroute site has the lowest. The values of equitability index are between 0.36 and 0.44. These values indicate that beetles families distribution is less equitable in the disturbed areas (Table 4). In the forest areas, more families were identified at Gare site (37 families) with a higher diversity index (2.98). Fewer families have been identified at Filtisac site. The values of equitability index are between 0.48 and 0.54. Almost all of the equitability index are just above average (0.50). This indicates that the distribution of beetle families in the forest is more or less equitable (Table 4). Beetles are more diverse in the forest than in Disturbed areas.

Beetles abundance and family richness in relation with plant species diversity

In forest areas: Beetle abundance and family richness increase with plant species number. Filtisac site has the smallest plant species number (11 ± 2.31 species), the lowest abundance and family richness of beetle respectively 53.66 ± 7.26 individuals and 29 families. Gare site has the largest plant species number (19.50 ± 0.87 species), the greatest abundance and family richness of beetle respectively 115.5 ± 22.19 individuals and 37 families. Statistical analysises indicate that plant species diversity has a significant positive effect on beetle's abundance and family richness when considering the correlation coefficient r and the probability p (Table 5, Figure 3 et 4).

In disturbed areas: Beetle family richness increases with the plant species number. Autoroute site has respectively the lowest plant species number (5.75 ± 0.85 species) and the lowest beetle family richness (23 families). Sagbe site has respectively the largest plant species number (17.50 ± 1.58 species) and the largest beetle family number (32 families). Statistical analysis indicates that plant species diversity has a positive and significant effect when considering correlation coefficient r and probability p on beetle family richness (Table 6 et Figure 5). However, the abundance of beetle does not increase with the plant species number. Autoroute site which has the lowest average number of plant species (5.75 ± 0.85 species) has an higher average abundance of beetle (88.75 ± 9.28 individuals) than those of Filtisac and Sagbé site, which have each, an average number of plant species higher than that of Autoroute site. Statistical analysis indicates that plant species diversity has no significant effect when considering the correlation coefficient r and the probability p, on beetles abundance (Table 6).

Tableau 6. Correlation between floristic richness, beetle abundance and family richness in human disturbed areas

	Beetles abundance	Beetles families Richness	Floristic richness
Beetles abundance	-	r = 0,338 p = 0,661	r = 0,153 p = 0,846
Beetles famillies richness	r = 0,338 p = 0,661	-	r = 0,959 P = 0,044

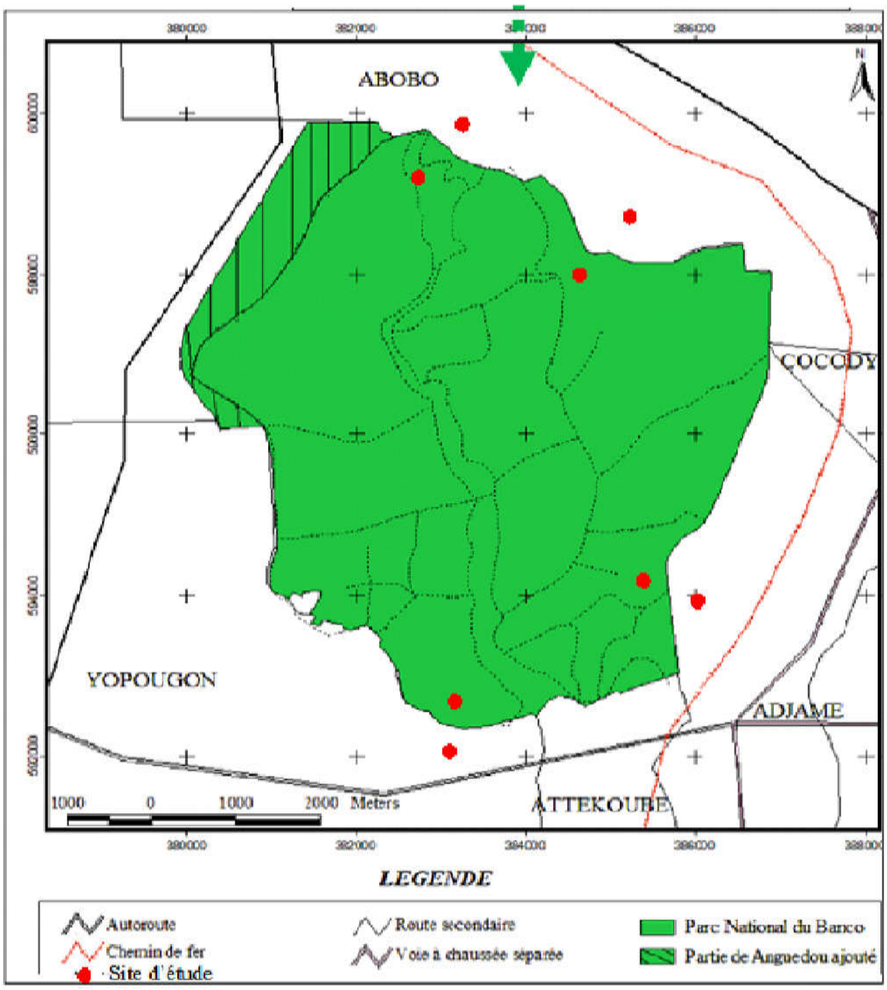

Figure 1. Banco National Parck Localization in Côte d'Ivoire (Tiébré and al., 2015)

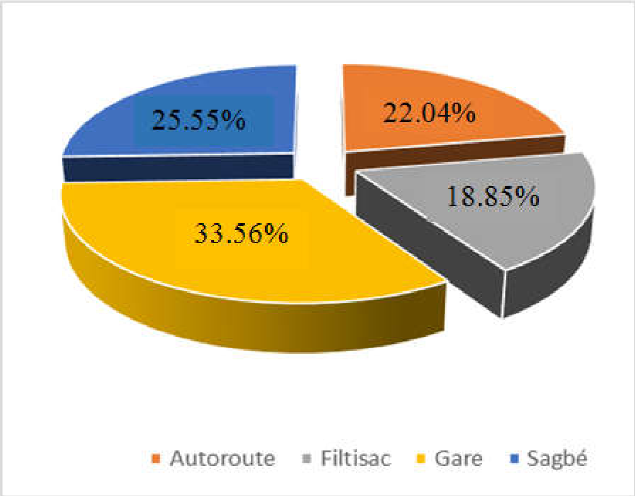

Figure 2. Percentage of beetles caught per site

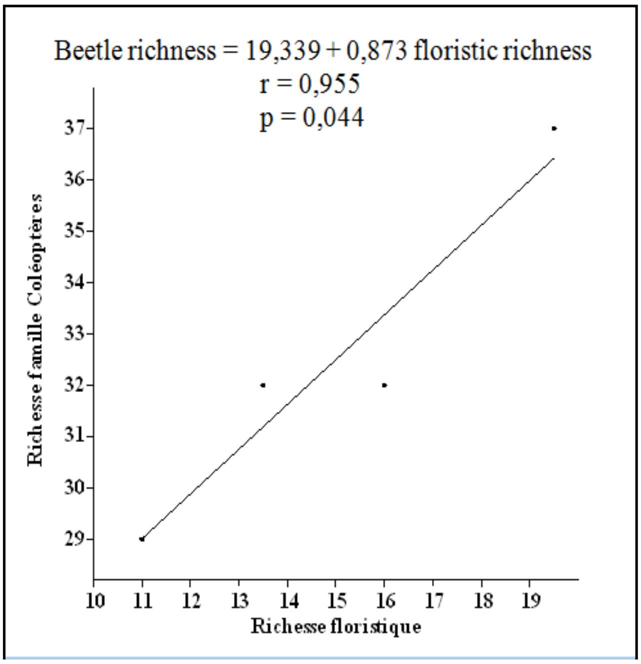

Figure 3. Beetles family richness linear regression compared to floristic richness in Banco National Park

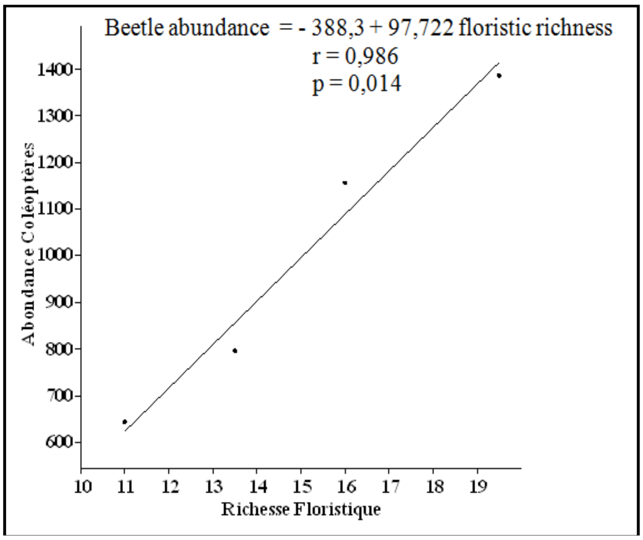

Figure 4. Beetle abundance linear regression compared to floristic richness in Banco National Park

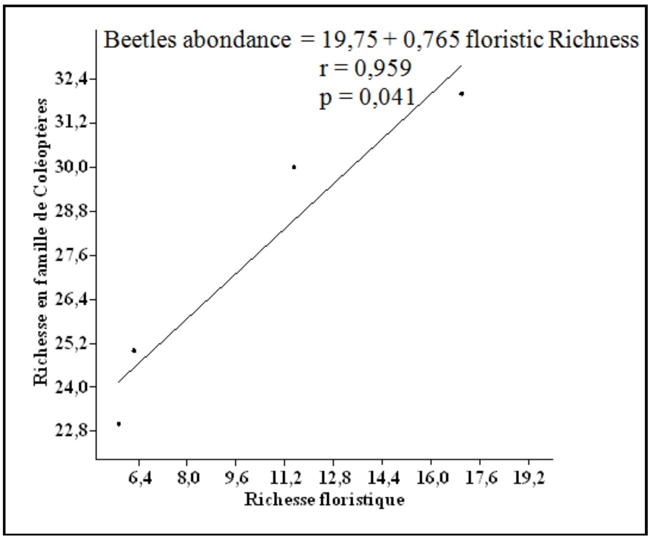

Figure 5. Beetle family richness linear regression compared to floristic richness in human disturbed areas

DISCUSSION

The study of the floristic composition in the disturbed areas and Banco National Parc revealed 155 species divided into 136 genera belonging to 50 families. In disturbed areas, 84 species divided into 71 genera belonging to 27 families have been identified. In the forest area, 71 species divided into 65 genera belonging to 32 families have been identified. These results are different from those of N'Guessan (2013), who has listed 258 plant species in the Banco National Park. This could be due to the fact that whether this study took place just at the margin of the Banco National Park or to the surface sampled number. The inventory showed that the most represented families in species number in the forest area are Leguminoseae, Araceae, Apocynaceae, Dichapelataceae, Malvaceae and Rubiaceae. This situation is not specific to the Banco National Park. Indeed, the majority of Ivorian forests are dominated by the same plant families (Nusbaumer, 2005; N'Da *et al.,* 2008; Goné Bi *et al.,* 2013 ; Adou Yao *et al.,* 2013). Concerning the disturbed areas floristic composition, Poaceae family is the most represented, followed by Compositeae, Euphorbiaceae, Cyperaceae, Leguminoseae and Rubiaceae. The importance of Poaceae in this area may be explained by the fact that these taxa have a very high tillering possibility and a higher regrowth rate after grazing, when the environmental conditions are favorable (Salette, 1970). These results corroborate the observations of Adjanohoun (1962). According to him, in his phytosociology study on the savannahs of lower Ivory Coast, he found that species of Poaceae family were the most numerous, followed by Leguminoseae and Cyperaceae.

The low average values of Shannon index in the forest according to Frontier and Piochod-Viale (1995) classification, between 1.08 and 1.43, could be explained by our studying carried out at the periphery of the Banco National Park. This area is under significant pressure, because of its proximity and easy access to the population. This pressure could result in the removal of certain species for food and other purposes. In addition, the lowest plant diversity could be explained by the canopy closure. The canopy opening caused by phenomena such as windfall, favors the light arrival on the aboveground. This light will eventually lead to the heliophilous species seed dormancy emergence, hence the regeneration of new individuals. Indeed the luminous intensity conditions species growth and the survival thus their distribution. This observation is valid at all stages of development (Kobbe 1999, Webb et Peart, 2000). On the other hand, canopy closing does not favor such phenomena, but will rather prevent light penetration to the undergrowth. This could contribute to the diversity reduction. Characteristic species poverty of psammohygrophilous forests in general and Banco's forest in particular is remarkable. These are *Turreaenthus africanus* and *Heisteria parviflora*. Concerning the species *Turraeanthus africanus*, we note its total absence on all the surveys carried out on the forest sites. As for the species *Heisteria parviflora*, we note the weak presence of this one in all the forest studied sites. This situation could be explained by the forest sites disturbance. Because these species are designated to characterize the forest, they should be abundant especially in the undergrowth. Some species, such as *Angylocalyx oligophyllus* and *Chrysophyllum subnum*, have been particularly abundant.

The floristic inventory associated to entomological study has shown that beetles abundance and family richness increase with plant diversity, except in the disturbed areas where beetles abundance does not increase with plant diversity. Previous studies showed that a landscape heterogeneous is associated with greater arthropods species richness, including butterflies (Kerr, 2001 ; Weibull *et al.,* 2003), carabes (Weibull et Ostman, 2003) or spiders (Clough *et al.,* 2005). This relationship can be explained, in particular, by the fact that the number of habitats increases when the landscape is more heterogeneous (Maisonhaute, 2010). This increases the likelihood for arthropods to find an optimal site for hibernation, oviposition, or larval development (Weibull et Ostman, 2003). According to landscape studies, spatial organization and landscape dynamics could substantially influence organisms living. This can be explained by the fact that the different elements of the landscape are as much colonizable habitats by organisms, and within which populations can develop (Fahrig, 2013). Kra (2010), found that beetles are more abundant and diversified in heterogeneous habitat food crops in Oumé, in Côte d'Ivoire's forest zone. The heterogeneity of the landscape composition increases communities diversity as it allows the provision of diverse habitats (ecological niches) and increases the possibilities for complementing resources (Fahrig *et al.,* 2011 ; Perovic *et al.,* 2015). Heterogeneity of configuration also has a positive effect on species diversity as it reduces the costs of movement between habitats (Perović *et al.,* 2015).

According to Siemann *et al.* (1998), Schaffers *et al.* (2008), plant diversity positively influences the richness and abundance of herbivorous insects but also those of their predators, because in habitats rich in plant species predators may be favored by greater diversity and quantity of prey but also by a greater habitats diversity (Langellotto et Denno, 2004; Haddad *et al.,* 2009; Scherber *et al.,* 2010). An increase in plant diversity implies an increase in the generalist herbivorous insect's diversity. This increase in generalist herbivorous insects is also related to an increase in the generalist herbivorous insect's diversity of their predators. This relationship between herbivorous and predators leads to an increase in insect diversity in the environment (Haddad *et al.,* 2009). The study of the relationship between plant species diversity and beetle populations in the disturbed areas shows that the specific plant diversity has a positive influence on beetle's families richness. However, it has no influence on abundance. This contrast in progression between the plant specific diversity and beetle abundance in disturbed areas is explained by the presence of man activities in these areas. For example, in Sagbe site, where the greatest number of plant species were collected, beetle abundance obtained is lower than those obtained at Autoroute and Gare site where plant diversity is low. In Sagbé site, sampling was very difficult. Traps (yellow ground traps and yellow height trap) were picked up by local residents and destroyed by the cattle. This resulted in a loss of important data that could affect the beetle abundance. It can also be pointed out that the floristic composition of the most abundant trees in each study site is another factor that could explain the variations in abundance per plot. Indeed, some tree families take in many more phytophagous species than others (Cerambycidae and other xylophages with Fabales) (Lamarre *et al.,* 2011). Outside, biotic factors (diversity of plant species), the beetle abundance in a particular habitat could also be explained by abiotic factors such as the physico-chemical parameters of the soil (soil type, humidity, pH), especially for the terricolous beetles (Carabidae) (Irmler et Hoernes, 2003).

Conclusion

The dominant families of plant were Poaceae, compositeae, Euphorbiaceae, Cyperaceae, Leguminoseae, Rubiaceae, Apocynaceae, Convolvulaceae, Araceae, Dichapetalaceae, Leguminoseae and Malvaceae. Low qualitative and quantitative floristic diversity is obtained in both anthropised and forest areas. Beetles were more abundant in anthropized areas but more diverse in the forest. The abundance and diversity of Beetles were correlated with the specific plant diversity in the forest area. This is not the case in the disturbed areas. Plant diversity is very important for the abundance and diversity of Beetles in a habitat but human disturbance has a negative effect on this link between plant communities and Beetle populations.

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