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Assessment of beetle abundance and diversity by four methods of capture in the west-central part of Oumé, Ivory Coast

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1 SUMMARY

Different methods of trapping for insect biodiversity related investigations are recommended, depending on the biological group studied. The aim of this study was to compare the efficiency of four trapping methods in capturing beetles in relation to habitat. The methods were: (1) yellow ground traps, (2) yellow aerial traps, (3) Malaise traps and (4) pitfall traps. We collected samples in 8 land use types: (i) primary forests (PF), (ii) secondary forests (SF), (iii) multi-species plantations (MP), (iv) 10-year-old teak plantations (TK10), (v) 4-year-old teak plantations (TK4), (vi) rural fallows (FA), (vii) mixed-crop fields (MC) and (viii) cocoa plantations (CC). We used 31 traps/site: 10 pitfall traps, 10 yellow ground traps, 9 yellow aerial traps and 2 Malaise traps. The traps captured 2195 specimens of Coleoptera (Malaise traps - 787 specimens, pitfall traps - 406 specimens, yellow aerial traps - 487 specimens, and yellow ground traps – 515 specimens). The Malaise and pitfall traps collected the highest number of specimens in mixed-crop fields. The yellow ground traps and yellow aerial traps collected the highest number of specimens in cocoa plantations and in primary forests. Beetle abundance and diversity varied according to the trap and the land use type. Although Malaise traps collected more families and individuals, combining different traps is recommended for the best sampling of Coleopteran taxa.

2 INTRODUCTION

The diversity of insects in an area or a given habitat may be measured by comparing data from inventory studies. The inventories may be carried out by different methods of capture, suitable for collecting diverse groups of insects occurring in a study area. For example, pitfall traps are used in many studies of litter fauna, e.g., Carabidae (Tuovinen *et al.*, 2006; García *et al.*, 2000; Helenius *et al.*, 2006) while Malaise traps are suitable for capturing actively flying insects (Carrières, 2001; Tomasovic, 2001). In general, the use of several capture methods is necessary for inventory of species with diverse life histories such as beetles, which constitute the largest insect order (Lhoir *et al.*, 2003). Braet *et al.* (2000) recommended that insects in tropical environments would be more effectively inventoried with combined use of different trapping methods.

So far, investigation on beetles using several methods of capture has not been conducted in Ivory Coast. In the present study, we investigated the efficiency of different trapping methods in capturing different beetle groups in relation to type of land use. Beetle abundance and diversity, effectiveness of capturing method, and family affiliation, were investigated using Malaise traps, yellow aerial traps, pitfall traps and yellow ground traps.

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3 MATERIALS AND METHODS

3.1 Study site: The study site was located in the west-central part of Ivory Coast, near Oumé, 6°30'N, 5°31'W. The region is particularly interesting for studying the impact of different land use on biodiversity. The land there is being transformed from primary forest to agricultural land and plantation forestry, which play a key role in the economic development of the region.

3.2 Experimental design: Two experimental fields of the forest development company (SODEFOR) and the rural domain (RD) were, utilized, with a grid system of 107 sampling sites (each separated from the other by a distance of 200 m). We took samples of beetles in 8 land use types using 31 traps per site (4 sites per land use type): 2 Malaise traps (MA), 10 pitfall traps (PT), 10 yellow ground traps (YGT) and 9 yellow aerial traps (YAT). The land use types were primary forests (PF), secondary forests (SF), multi-species plantations (MP), 10-year-old teak plantations (TK10), 4-year-old teak plantations (TK4), rural fallows (FA), mixed-crop fields (MC) and cocoa plantations (CC). For pitfall traps we used plastic cups (10 cm in diameter), set in 10 cm deep holes flush with the ground level. The traps were covered by a dead leaf, leaving space between the cover and the ground, and were half filled with soapy water to reduce surface tension.

For yellow traps, we used yellow containers measuring 15 cm in diameter and 10 cm in depth with soapy water at the bottom. The insects attracted by the container's colour were collected in the water. The Malaise intercept trap was invented by Malaise in 1937 for collecting flying insects (Southwood, 1978; Schneider & Carrières, 2008).
The sampling protocol was based on designs and methologies by Obrtel (1971), Luff (1975) and Baars (1979). At each sampling site, two 50-m-long transects set 10 m apart were established. On each transect, 5 points were designated at 10 m intervals. A pitfall trap, yellow ground trap, and three aerial traps fixed to a 2-m-high iron rod were positioned 1 m apart in a triangular arrangement at each sample site. Two iron rods were available for each of the 50-m-long transect. A Malaise trap was also used on each transect of every site. The two Malaise traps were positioned in a perpendicular arrangement at each sample site. Soapy water was used in pitfall traps, yellow ground and aerial traps, while 70% ethanol was used in the Malaise trap collecting containers. Samples were collected every 48 h. The first samples were collected during the dry season (July 28 to August 28, 2004) and the second in the same period in the following year, with a total of 32 sites being sampled for each period of sampling.

3.3 Data analysis: Diversity was estimated by Shannon and Shannon-Weaver indices. The Shannon index was computed using EstimateS version 7.5 (Colwell, 2005). Beetle diversity and abundance values in traps were compared using the Kruskal-Wallis non-parametric test and variance analysis with a factor (p = 0.05) completed by the Least Significant Difference (LSD) test (Statistica 6.0). A principal component analysis (PCA) using ADE-4, Windows version (Thioulouse *et al*., 1977), allowed us to show beetle affinity to traps and trap effectiveness according to land use type. The insect identification keys consulted were those of Delvare & Aberlenc (1989), Lawrence *et al.* (1999), and Leraut (2003). Beetles were identified to family level, and some to species level. Analysis was conducted on three groups of beetles: abundant group (n ≥ 100 specimens of a total catch), common group (n 10 ≤ 100 specimens of a total catch), and rare group (n < 10 specimens of a total catch).

4 RESULTS

4.1 Catch analysis: The Malaise and pitfall traps captured more specimens in mixed-crop fields (MA-211 individuals, on average 52.75/site and PT-92 individuals, on average 23/site)(Fig. 1 and Fig. 2**)**.The yellow aerial traps and yellow ground traps captured more individuals in primary forests and in cocoa plantations, respectively (YAT-83 individuals, on average 23.94/ site and YGT-91 individuals, on average 22.75/ site) (Fig. 3 and Fig. 4). The lowest catches were observed in 4-year-old teak plantations for Malaise traps (51 individuals, on average 12.75/ site), yellow ground traps (20 individuals, on average 5/ site), yellow aerial traps (22 individuals, on average 5.5/ site) and in primary forests for pitfall traps (19 individuals, on average 4.75/ site). Analysis of catches for each trap per land use type differed significantly for Malaise traps (p = 0.001), pitfall traps (p = 0.025), yellow ground traps (p = 0.001), and for yellow aerial traps (p = 0.0120). There were clear differences in catches in each trap per land use type (Fig. 1, Fig. 2, Fig. 3, and Fig. 4).

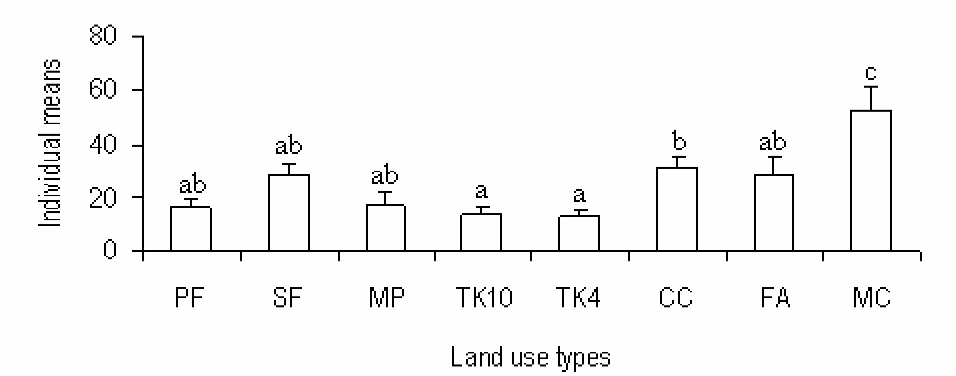

Figure 1: Beetles caught using Malaise traps in different land use types in Ivory Coast: PF (primary forests), SF (secondary forests), MP (multi-species plantations), TK10 (10-year-old teak plantations), TK4 (4-year-old teak plantations), CC (cocoa plantations), FA (rural fallows), MC (mixed-crop fields). All values are given as the mean ± standard errors and means with the same letter are not significantly different at the 5% level.

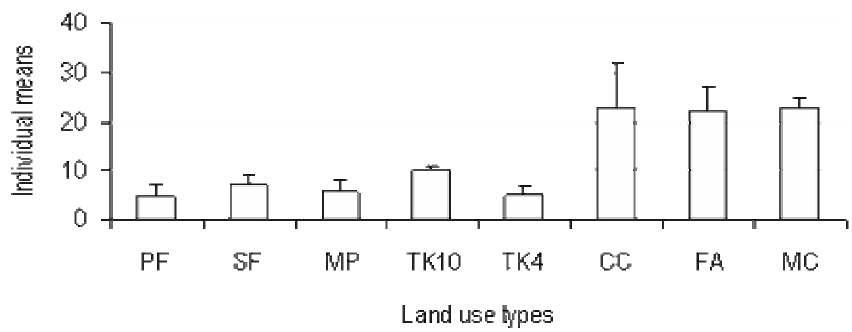

Figure 2: Beetles caught with pitfall traps in different land use types in Ivory Coast: PF (primary forests), SF (secondary forests), MP (multi-species plantations), TK10 (10-year-old teak plantations), TK4 (4-year-old teak plantations), CC (cocoa plantations), FA (rural fallows), MC (mixed-crop fields). All values are given as the mean ± standard errors.

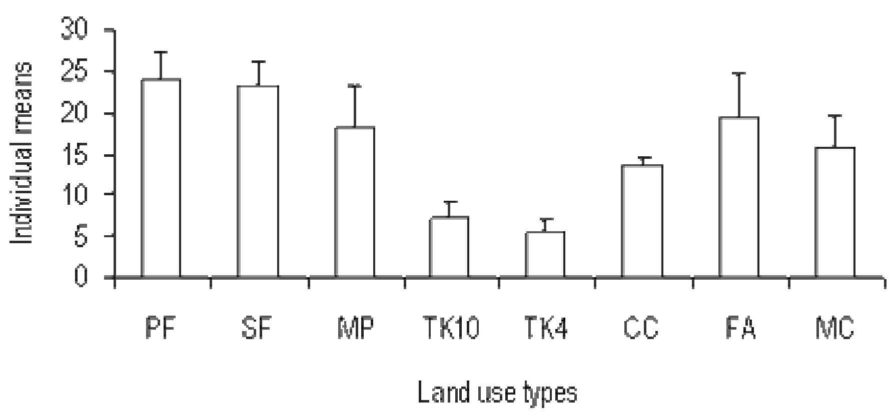

Figure 3: Beetles caught with yellow aerial traps in different land use types in Ivory Coast: PF (primary forests), SF (secondary forests), MP (multi-species plantations), TK10 (10-year-old teak plantations), TK4 (4-year-old teak plantations), CC (cocoa plantations), FA (rural fallows), MC (mixed-crop fields). All values are given as the mean ± standard errors and means with the same letter are not significantly different at the 5% level.

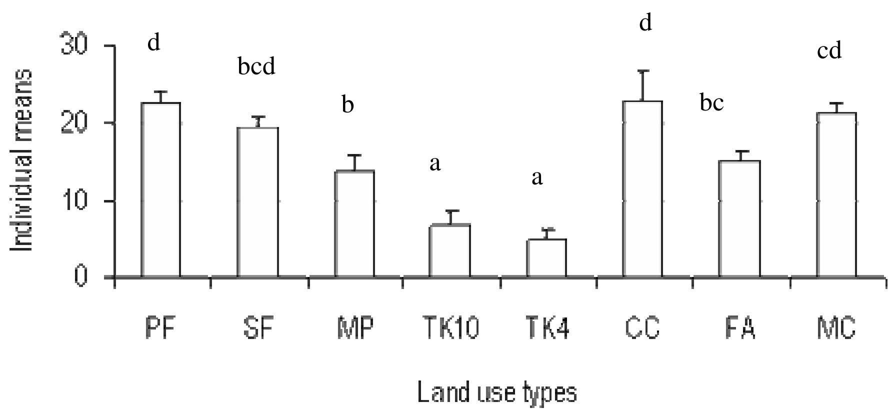

Figure 4: Beetles caught with yellow ground traps in different land use types in Ivory Coast: PF (primary forests), SF (secondary forests), MP (multi-species plantations), TK10 (10-year-old teak plantations), TK4 (4-year-old teak plantations), CC (cocoa plantations), FA (rural fallows), MC (mixed-crop fields). All values are given as the mean ± standard errors and means with the same letter are not significantly different at the 5% level.

4.2 Assessment of beetle diversity: Beetle diversity did not differ significantly between the land use types (Table 1), but was relatively higher in mixed-crop fields for Malaise traps, yellow ground and aerial traps and in fallows for pitfall traps. The lowest diversity was found in primary forests for Malaise traps, yellow ground traps, and yellow aerial traps and in 10-year-old teak plantations for pitfall traps (Table 1). The variation in catches between traps allowed us to do a principal component analysis on beetle abundance and group them into different categories. The families that formed abundant groups were Carabidae, Chrysomelidae, Histeridae, Mordellidae, Nitidulidae, Scarabaeidae, Scolytidae and Staphylinidae. The common groups were: Buprestidae, Cerambycidae, Cleridae, Coccinellidae, Curculionidae and Lycidae. The rare groups were: Anobiidae, Anthicidae, Apionidae, Attelabidae, Cantharidae, Dermestidae, Elateridae, Erotylidae, Lagriidae, Oedemeridae, Phalacridae, Platypodidae, Pselaphidae, Scydmaenidae, Silvanidae, and Tenebrionidae (Table 2).

Table 1: Shannon diversity indices for beetles caught using different trapping methods YGT (yellow ground trap), YAT (yellow aerial trap), MA (Malaise trap), PT (pitfall trap) in different land use types PF (primary forests), SF (secondary forests), MP (multi-species plantations), TK10 (10-year-old teak plantations), TK4 (4-year-old teak plantations), CC (cocoa plantations), FA (rural fallows), MC (mixed-crop fields), in Ivory Coast.

Trapping method	**Land use types**							
	PF	SF	MP	TK10	TK4	CC	FA	MC
MA	1.75	**2.11**	**2.1**	**2.07**	1.79	**2.01**	**2.1**	**2.24**
PT	1.67	1.47	1.65	0.87	1.27	1.66	**2.1**	1.77
YAT	1.08	1.51	1.33	1.8	1.16	1.85	1.95	**2.08**
YGT	1.18	1.39	1.85	1.61	1.24	1.78	2.11	1.93

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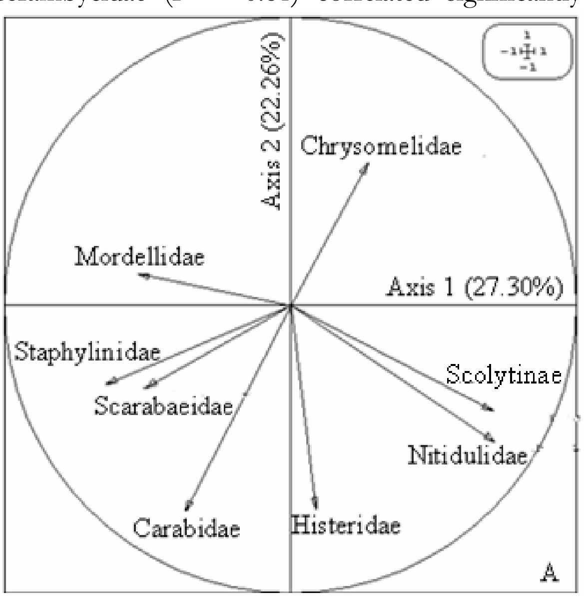
Table 2: Different beetle families (arranged in order of abundance) captured using different trapping methods: YGT (yellow ground traps), YAT (yellow aerial traps), MA (Malaise traps), and PT (pitfall traps).

Beetle family	**Trapping methods**					**Group**
	YGT	YAT	PT	MA	Total	
Chrysomelidae	198	248	8	134	588	Abundant group
Staphylinidae	60	16	60	187	323	
Nitidulidae	100	72	74	22	268	
Scarabaeidae	19	35	36	64	154	
Carabidae	11	3	102	27	143	
Histeridae	32	18	68	0	118	
Mordellidae	3	7	3	99	112	
Scolytidae	55	13	36	2	106	
Buprestidae	3	34	2	48	87	Common group
Curculionidae	8	13	13	42	76	
Cerambycidae	2	1	0	42	45	
Cleridae	2	2	0	41	45	
Coccinellidae	2	9	0	33	44	
Lycidae	2	3	0	23	28	
Pselaphidae	3	3	1	1	8	Rare group
Elateridae	1	0	1	5	7	
Platypodidae	0	2	1	3	6	
Silvanidae	3	2	1	0	6	
Scydmaenidae	2	1	0	2	5	
Erotylidae	3	0	0	2	5	
Dermestidae	2	0	0	2	4	
Attelabidae	2	1	0	1	4	
Lagriidae	0	0	0	3	3	
Cantharidae	0	0	0	2	2	
Apionidae	1	1	0	0	2	
Anthicidae	1	1	0	0	2	
Phalacridae	0	1	0	0	1	
Anobiidae	0	0	0	1	1	
Oedemeridae	0	0	0	1	1	
Tenebrionidae	0	1	0	0	1	
Total	515	487	406	787	2195	

4.3 Affinity between traps and beetle groups: For the abundant beetles, the component analysis (CA) revealed that Nitidulidae (r = 0.71) and Scolytinae (Curculionidae) (r = 0.71) correlated significantly with principal axis 1 (Fig. 5A). Axis 2 was correlated significantly with Carabidae (r = 0.72) and Histeridae (r = 0.71). The combining of the two axes gave 49.56% of the total inertia (27.30% for axis 1 and 22.26% for axis 2). Family projections in the factorial plan indicated that Nitidulidae and Scolytinae were affiliated with the yellow ground traps (YGT) according to axis 1 (Fig. 5B). In the same way, Carabidae and Histeridae were affiliated with the pitfall traps (PT) along axis 2. The significant correlation of the variables on axis 1 were opposite to the yellow ground traps and Malaise traps (MA) according to their projection on this axis. The yellow aerial traps (YAT) and the pitfall traps (PT) were distant to their projection on axis 2 due to significant correlation with Carabidae and Histeridae. The variability observed could be explained by insect movements. The insects that fly well, e.g., Chrysomelidae, were captured by the elevated traps while the insects that occur mainly on the ground like Carabidae, Staphylinidae and Histeridae, were mostly captured by the ground traps. For the common beetles, the component analysis indicated that Buprestidae (r = -0.73), Coccinellidae (r = -0.85), Lycidae (r = -0.75) and Cerambycidae (r = -0.81) correlated significantly with axis 1 while axis 2 correlated significantly with Curculionidae (r = 0.78) (Fig. 6A). The two axes accounted for 76.78% of total inertia (52.26% for axis 1 and 24.51% for axis 2). The beetle family projection in the factorial plan revealed that families that correlated with axis 1 characterized the Malaise traps (Fig. 6B). The families distant to the Malaise traps (captured in yellow ground traps, yellow aerial traps and pitfall traps) were projected on axis 1. The significant correlation of Curculionidae with axis 2 did not make a clear distinction between trapping methods (Fig. 5A and Fig. 5B, Fig. 6A and Fig. 6B).

4.4 Trap effectiveness according to land use type: The component analysis revealed that Malaise traps (r = 0.83) and yellow ground traps (r = 0.80) correlated significantly with axis 1. The second axis was correlated significantly with the yellow aerial traps (r = -0.73) (Fig. 7A). The combining of the axes gave 79.76% % of the total inertia (52.89% for axis 1 and 26.87% for axis 2). Trap projections in the factorial plan indicated that Malaise traps and yellow ground traps characterized mixed-crop fields (Fig. 7B). These traps were distant to the mixed-crop fields, rural fallows and cocoa plantations and the teak plantations according to axis 1. The yellow aerial traps characterized the primary forests, secondary forests and the multi-species plantations well. The primary forests were distant to the mixed-crop fields and cocoa plantations according to axis 2 (Fig. 7A and Fig. 7B).



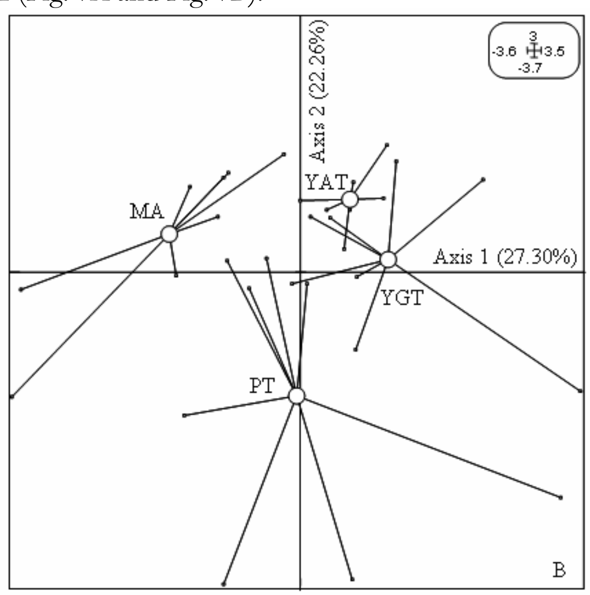


Figure 5: Affinity between traps and the abundant beetle group: **A**. Correlation circle; **B**. Star projections on factorial plan (MA, Malaise traps; PT, pitfall traps; YAT, yellow aerial traps; YGT, yellow ground traps)

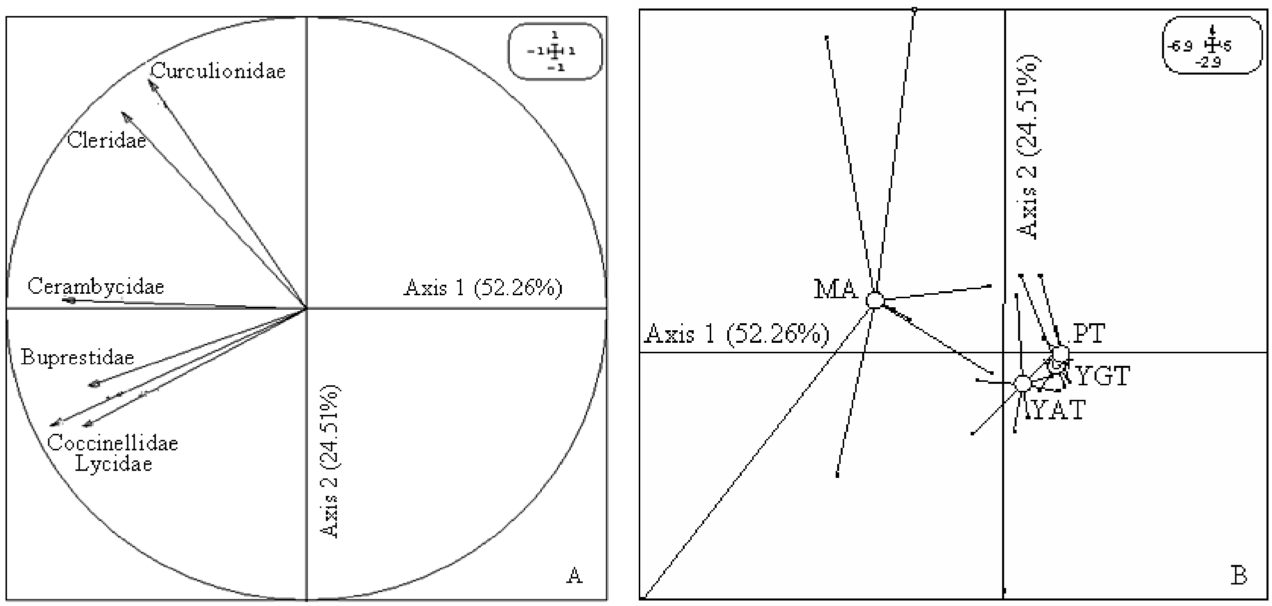


Figure 6: Affinity between traps and the common beetle group: A. Correlation circle; B. Stars projections on factorial plan (MA, Malaise traps; PT, pitfall traps; YAT, yellow aerial traps; YGT, yellow ground traps).

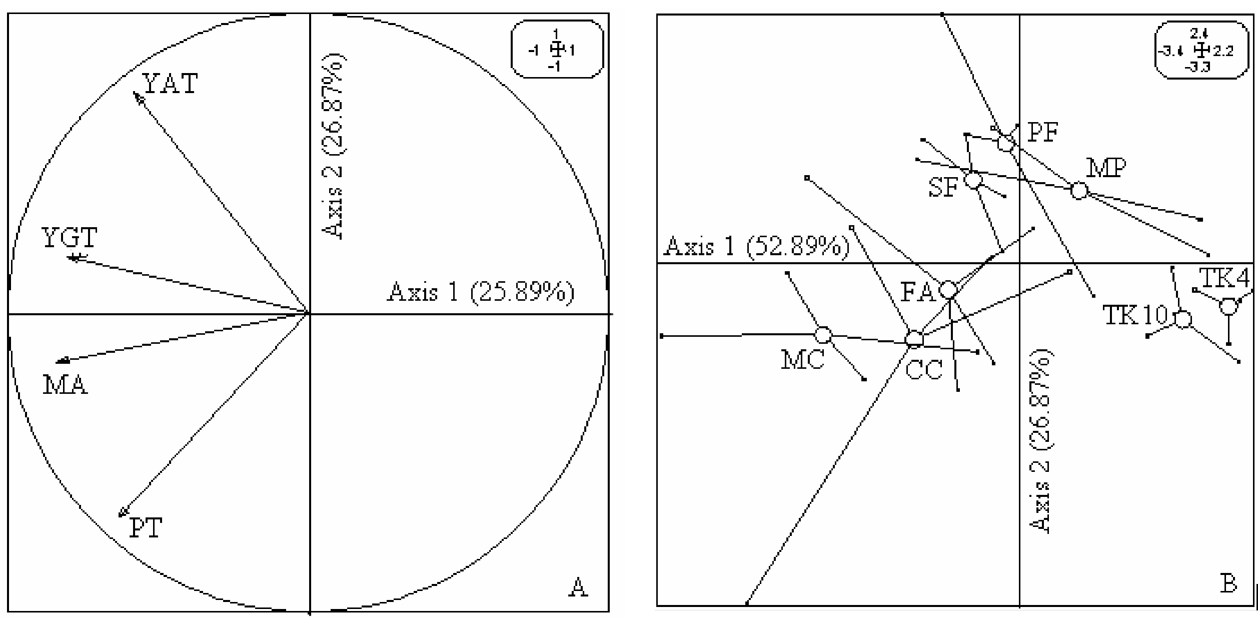


Figure 7A : Trap effectiveness according to land use types: A. Correlation circle (YAT, yellow aerial traps; YGT, yellow ground traps; MA, Malaise traps; PT, pitfall traps)
Figure 7B: Star projections on factorial plan (PF, primary forests; SF, secondary forests; MP, multi-species plantations; TK10, 10-year-old teak plantations; TK4, 4-year-old teak plantations; CC, cocoa plantations; FA, rural fallows; MC, mixed-crop fields).

5 DISCUSSION

The abundance and diversity of beetles, the effectiveness of traps in different land use types, and the affiliation of beetle family to method of capture were evaluated. The results showed that diversity and abundance vary according to land use type and the data captured was influenced by the type of trap used. Malaise and pitfall traps captured more individuals in mixed-crop fields where the majority of tall trees were cut down and only shrubs or herbaceous vegetation were present. The beetles could easily fly from one habitat to another and in the process be intercepted by the Malaise traps.

According to Melbourne (1999), vegetation structure influences trap capacity to capture insects. Schneider & Carrières (2004), working in open habitats, captured Sphecidae species with Malaise traps only and not with any another type of trap. If Malaise traps are set in a suitable place, they are able to quickly provide a preliminary overview of the local insect fauna (Carrières, 2001). The lowest Malaise trap catches were observed in 4-year-old teak plantations where undergrowth formed by Chromolaena odorata obstructed free flying. The principal component analysis confirmed high capture of beetles by Malaise traps in mixed-crop fields.

The high abundance and diversity in mixed-crop fields were discussed by Kra et al. (2008). In addition to Malaise traps, yellow ground traps also characterized the mixed-crop fields well. Malaise traps and yellow ground traps collected fewer catches in mixed-crop fields, rural fallows and cocoa plantations than in the 10-, and 4-year-old teak plantations. These traps captured the most specimens in mixed-crop fields and cocoa plantations, respectively. For the yellow ground traps to attract insects, they need to be clearly visible. A vegetation opening near the trap is also necessary for insect to be captured in the yellow ground traps.

The pitfall traps captured most specimens in the mixed-crop fields, mainly the insects that move on the ground. The effectiveness of pitfall traps is also linked to the vegetation around the trap (Greenslade, 1983). In yellow aerial traps, the highest catches were observed in primary forests. Indeed, the most abundant family in the yellow aerial traps was Chrysomelidae. On the other hand, Carabidae and Histeridae were captured mainly in the pitfall traps. Chrysomelidae are phytophagous and are generally found on the foliage. The yellow aerial traps were often placed near the foliage, and consequently they were likely to capture these phytophagous insects, which were dominant in the forests.

Although the yellow traps are recommended for catching Diptera and Hymenoptera (Noblecourt, 1993), the beetle family Chrysomelidae is also attracted to this type of trap. The Carabidae, Staphylinidae and Histeridae, which move mostly on the ground, were easily captured by the ground pitfall traps. The families, Nitidulidae and Scolytidae were collected in the yellow ground traps. Nitidulidae are often present on fruit that has fallen to the ground, low plants and desiccated corpses of dead animals (Leraut, 2003). All the traps that capture insects moving on the ground are characterized by the distant catch to those placed higher up like Malaise traps. The Buprestidae, Coccinellidae, Lycidae and Cerambycidae, which are good fliers, were abundantly collected in Malaise traps.

Pitfall traps did not capture Coccinellidae, Lycidae, Cerambycidae and Cleridae among the common beetles. Malaise traps captured most individuals among all of the traps, and therefore are recommended for beetle surveys, but their usefulness also depends on the vegetation structure. The yellow traps captured abundant insects because of their attractive colour imitating some flowers, but the non-flower-dwelling beetles were absent from these traps. The pitfall traps are suitable for collecting ground-dwelling beetles. The complementary abilities of different traps to collect different insects make it necessary to use them in combination with others for faunal inventories (Braet et al., 2000).

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6 CONCLUSION

The four trap types used in our experiment provided interesting results, but the choice of one of them or their combination depends on the research objectives. For the majority of general beetle samplings, Malaise traps are suitable. Yellow traps and pitfall traps are more specific for a number of ground-dwelling families. The best sampling of beetles requires a combination of different trapping methods because of the trap complementarities, which allow a better estimate of abundance, diversity and species richness in different land use types.

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