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Comparing Beetle Abundance and Diversity Values along a Land Use Gradient in Tropical Africa (Oumé, Ivory Coast)

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Kra Kouadio Dagobert, Jan Klimaszewsk, Doumbia Mamadou, Aidara Daouda, and Dagnogo Mamadou (2008) Comparing beetle abundance and diversity values along a land use gradient in tropical Africa (Oumé, Ivory Coast). *Zoological Studies* **47**(4): 429-437. Beetles are an important part of global biodiversity, and they contribute to most ecological processes that sustain various ecosystems. Their natural habitats are often influenced by human agricultural activities. In the context of the sustainable use of natural resources in tropical countries, an investigation was conducted in Ivory Coast to study the influence of habitat modification on beetles. A stratified sampling method was utilized. The aim of this work was to study beetle distribution, abundance, and diversity in agroecosystems along a land degradation gradient. This research demonstrated that beetle abundance and diversity values varied depending on land characteristics. Mixed-crop fields supported the most abundant and diverse beetle community. Beetle distribution and diversity are clearly affected by land transformation. http://zoolstud.sinica.edu.tw/Journals/47.4/429.pdf

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Agricultural activities cause more-prominent changes to land and vegetation characteristics on smaller temporal scales and at a larger spatial scale than most natural processes (Jepsen et al. 2005). The main consequences of such activities are reductions in forests, alterations in biodiversity, deterioration of soils, and possibly even desertification. Various studies have demonstrated that beetle assemblages are sensitive to human activities (Purvis and Fadl 2002, Cole et al. 2002, Klimaszewski et al. 2003, Hautier et al. 2003). Beetles constitute a large proportion of total insect biodiversity and play a pivotal role in trophic chains (Leraut 2003). They are influenced by habitat changes and are good indicators of environmental properties. Beetle studies in Africa, particularly in Ivory Coast where the economy is principally based on agricultural activities, can provide much-needed information on their sensitivity to such activities. We herein present preliminary data on beetle abundances, diversity levels, and distributions in different environments modified by agricultural activities. Additional investigations in the same study area are being conducted and will be published separately.

MATERIALS AND METHODS

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 human impacts on biodiversity because it is subjected to different types of primary forest conversion to agriculture and forestry, both of which play key roles in the economic development

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of the region. Two experimental fields of the Society for Forest Development (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 in 8 agroecosystems and utilized 29 traps per agroecosystem: primary forests (PF), secondary forests (SF), multi-species plantations (MP), 10-yr-old teak plantations (TK10), 4-yr-old teak plantations (TK4), rural fallow land (FA), mixed-crop fields (MC), and cocoa plantations (CC) (Fig. 1).

Four types of unbaited traps were used: pitfall traps, yellow ground traps, yellow aerial traps, and Malaise traps. The sampling protocol was based on a few key pitfall trap designs and methodologies (Luff 1975, Obrtel 1971, 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. At each sample point, a pitfall trap, yellow ground trap, and 3 aerial traps fixed to a 2-m-high iron rod were positioned 1 m apart in a triangular arrangement. Two Malaise traps were also used on each transect at every site. Formalin (2%) was added to a small quantity of soapy water in the pitfall, yellow ground, and aerial traps, and 70% ethanol was used for the collecting containers of the Malaise trap. Samples were collected every 48 h. The 1st sampling was conducted during the dry season (July to Aug. 2004) and the 2nd in the same period the following year (July to Aug. 2005), with a total of 32 sites being sampled.

Jaccard and Sorensen indexes were used

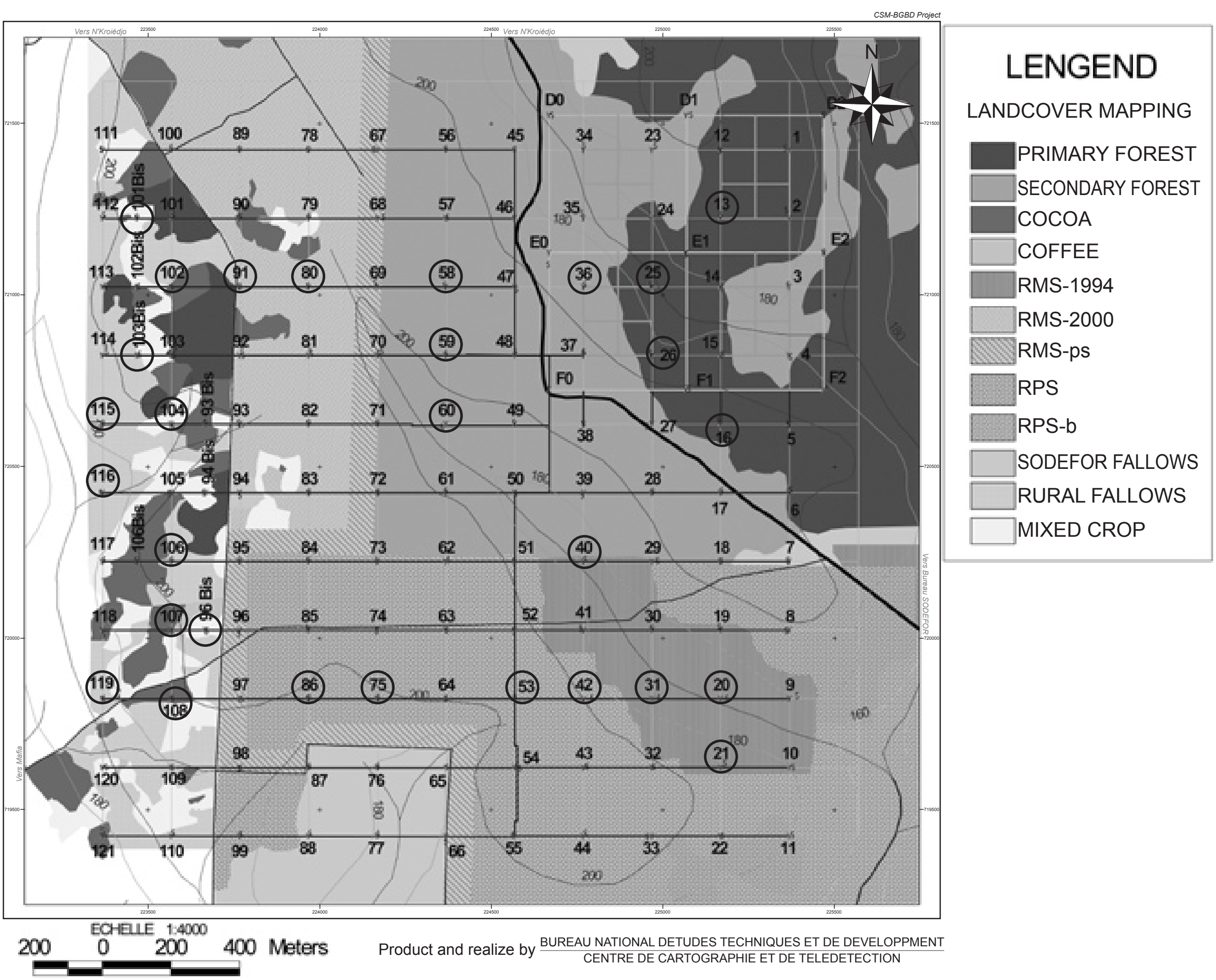

Fig. 1. Sampling grid. RMS-1994, TK10 (10-yr-old teak); RMS-2000, TK4 (4-yr-old teak; RPS (Reboisement Plurispécifique) or MP (multi-species plantations).

for coleopteran classification and were assessed using EstimateS 7.5 (Colwell 2005). Shannon and Shannon-Weiner indexes were used to evaluate the biodiversity richness and evenness indexes. The Shannon index is usually much more elevated than actual diversity. The interrelationship of this index with the sampling size provides the best evaluation of the population diversity from a given sample (Daget 1976 in Hautier et al. 2003). The Shannon-Wiener index is defined by comparing the Shannon index with a hypothetical Shannon index that would correspond to a maximal diversity, i.e., that in a real population where all species have the same coefficient (Lamotte 1995 in Hautier et al. 2003). These were performed for each agroecosystem (using EstimateS 7.5 for the Shannon index and Ecological Methodology 6.1 for the Shannon-Wiener index). A comparative study of all beetle diversity and abundance values in traps was performed 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 the impact of environmental changes on beetle abundances according to the kind of trap. We used the identification keys and pictures from Delvare and Aberlenc (1989), Lawrence et al. (1999), and Leraut (2003).

Table 1. Beetle abundances in different agroecosystems (data matrix for Fig. 2) (PF, primary forests; SF, secondary forests; MP, multi-species plantations; TK10, 10-yr-old teak plantations; TK4, 4-yr-old teak plantations; CC, cocoa plantations; FA, fallow fields; MC, mixed-crop fields)

Families of the Coleoptera	PF	SF	MP	TK10	TK4	CC	FA	MC	Total
Staphylinidae	13	46	25	18	15	42	78	86	323
Buprestidae	2	10	13	4	6	6	28	18	87
Coccinellidae	2	2	4	0	1	9	5	21	44
Chrysomelidae	143	119	76	35	22	52	60	81	588
Carabidae	7	8	10	30	12	26	28	22	143
Mordellidae	4	13	11	6	20	45	9	4	112
Curculionidae	11	31	5	4	2	6	10	7	76
Lycidae	1	1	0	0	0	0	6	20	28
Scydmaenidae	0	0	0	1	0	1	0	3	5
Cerambycidae	1	8	7	2	4	8	9	6	45
Nitidulidae	27	20	29	11	22	70	32	57	268
Erotylidae	1	0	1	1	0	0	0	2	5
Histeridae	3	5	10	1	2	7	47	43	118
Scarabaeidae	11	15	12	27	5	11	19	54	154
Scolytidae	15	5	10	4	0	59	3	10	106
Platypodidae	0	1	1	0	1	0	0	3	6
Phalacridae	0	0	0	0	0	0	0	1	1
Silvanidae	0	0	0	0	0	2	3	1	6
Cleridae	15	11	4	5	0	4	0	6	45
Anobiidae	0	0	0	0	0	0	1	0	1
Elateridae	0	2	1	1	1	2	0	0	7
Oedemeridae	0	0	0	1	0	0	0	0	1
Cantharidae	0	1	0	0	0	0	0	1	2
Apionidae	0	2	0	0	0	0	0	0	2
Anthicidae	0	1	0	0	0	0	1	0	2
Lagriidae	1	2	0	0	0	0	0	0	3
Pselaphidae	0	0	0	0	0	1	3	4	8
Dermestidae	0	0	0	0	0	2	1	1	4
Tenebrionidae	0	0	0	0	0	1	0	0	1
Attelabidae	2	0	1	0	0	0	1	0	4

RESULTS

In total, 2195 beetles were collected during 2 sampling seasons (Table 1). Beetle abundances significantly differed according to the Kruskal-Wallis non-parametric test (p = 0.0369). Abundances were greater in the mixed-crop fields (20.55%) than in the other agroecosystems. A high abundance in the mixed-crop fields was followed by that in cocoa plantations (16.13%). The lowest abundance was found in 4-yr-old teak plantations (5.15%). Across the sampled area (Fig. 1), the highest number of families and therefore diversity was found in the mixed-crop fields (22 families) followed by secondary forests (20 families). The lowest diversity occurred in 4-yr-old teak plantations (13 families). The families Chrysomelidae, Staphylinidae, and Nitidulidae were represented by the highest number of individuals, and their distributions differed according to habitat (Table 1, Fig. 2).

Beetle diversities between agroecosystems did not significantly differ according to the Kruskal-Wallis non-parametric test (p = 0.10), but they differed according to other biodiversity indexes (Table 2). Mixed-crop fields had the highest Shannon index, followed by fallow fields. Primary forests represented the lowest diversity according to the Shannon index. Evenness was nearly identical from 1 agroecosystem to another, meaning that species exhibited similar abundances (Fig. 3, Table 2).

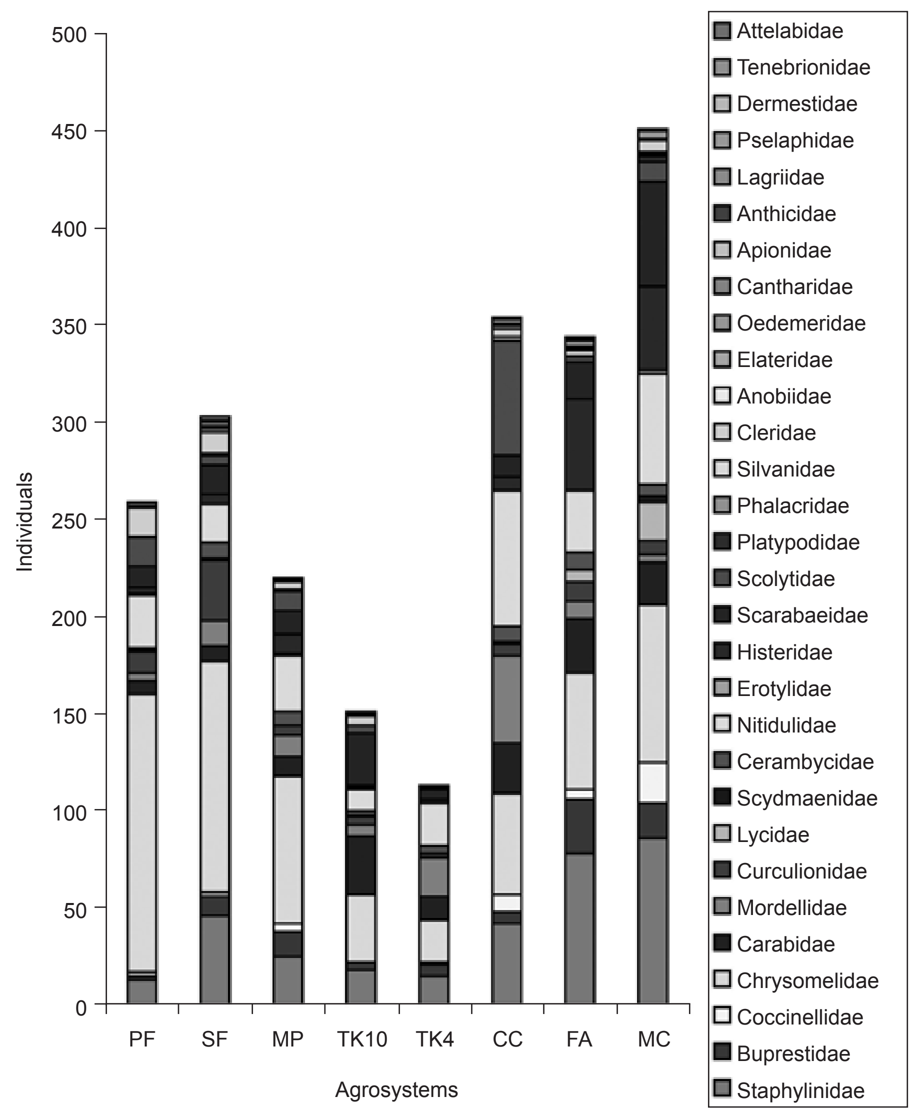

Fig. 2. Beetle abundances in agroecosystems. SF, primary forests; FS, secondary forests; MP, multi-species plantations; TK10, 10-yr-old teak plantations; TK4, 4-yr-old teak plantations; CC, cocoa plantations; FA, fallow fields; MC, mixed-crop fields.

There were clear differences in beetle diversity among agroecosystems. The classification according to the Sorensen index allowed us to separate or classify agroecosystems according to species richness (Table 3). Similarities were observed for primary forests with multi-species plantations, secondary forests with 4-yr-old teak plantations, and mixed-crop fields with cocoa plantations. The 10-yr-old teak system was most dissimilar to the remaining agroecosystems (Fig. 4, Table 3).

The Malaise traps captured a total of 787 individuals (35.85%), and yielded more beetle families and individuals than the other traps. Catches by the various traps significantly differed (p = 0.00008). Malaise traps collected the most beetles in the mixed-crop fields, followed by yellow ground traps, which yielded 515 individuals (23.46%). The lowest number of beetles capture was by the pitfall traps, with 406 individuals captured (18.50%). The results indicated that beetle abundance significantly varied among agroecosystems sampled by yellow ground traps (p = 0.00001), pitfall traps (p = 0.025), and Malaise traps (p = 0.0006). On the other hand, beetle abundances did not significantly differ when using in the yellow aerial traps (p = 0.077). The PCA revealed that the Malaise and yellow ground traps were significantly correlated with the principal axis (axis 1; Fig. 5). Combining Malaise and yellow ground traps yielded 52.89% of the principal axis information. The 2nd axis was represented by yellow aerial traps which provided 26.87% of the information. The projection of agroecosystems on axis 1 discriminated 2 groups. Mixed-crop fields, rural fallow fields, cocoa plantations, primary forests, secondary forests, and multi-species plantations formed the 1st group. The 2nd group was formed by teak plantations (Fig. 5). Among the families collected, the Staphylinidae was the most abundant in Malaise traps, the Nitidulidae was most abundant in ground traps, and the Chrysomelidae was most abundant in aerial traps.

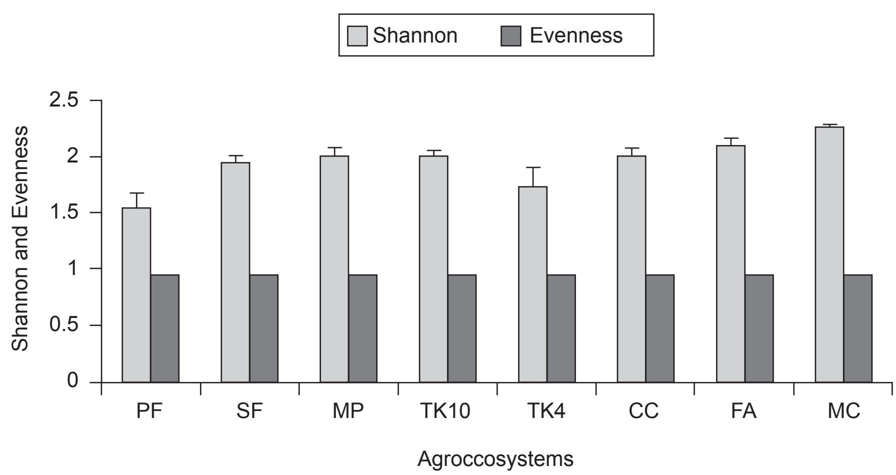

Fig. 3. Agroecosystem diversity estimated by the Shannon and evenness indexes. PF, primary forests; SF, secondary forests; MP, multi-species plantations; TK10, 10-yr-old teak plantations; TK4, 4-yr-old teak plantations; CC, cocoa plantations; FA, fallow fields; MC, mixed-crop fields.

Table 2. Shannon indexes (H), standard errors (SE), and evenness indexes (E) in different agroecosystems utilized in figure 3 (PF, primary forests; SF, secondary forests; MP, multi-species plantations; TK10, 10-yr-old teak plantations; TK4, 4-yr-old teak plantations; CC, cocoa plantations; FA, fallow fields; MC, mixed-crop fields)

	PF	SF	MP	TK10	TK4	CC	FA	MC
H	1.72 ± 0.13	2.12 ± 0.06	2.22 ± 0.07	2.17 ± 0.05	2.13 ± 0.17	2.3 ± 0.08	2.32 ± 0.07	2.41 ± 0.02
SE	0.13	0.06	0.07	0.05	0.17	0.08	0.07	0.02
E	0.96	0.96	0.96	0.95	0.93	0.95	0.95	0.96

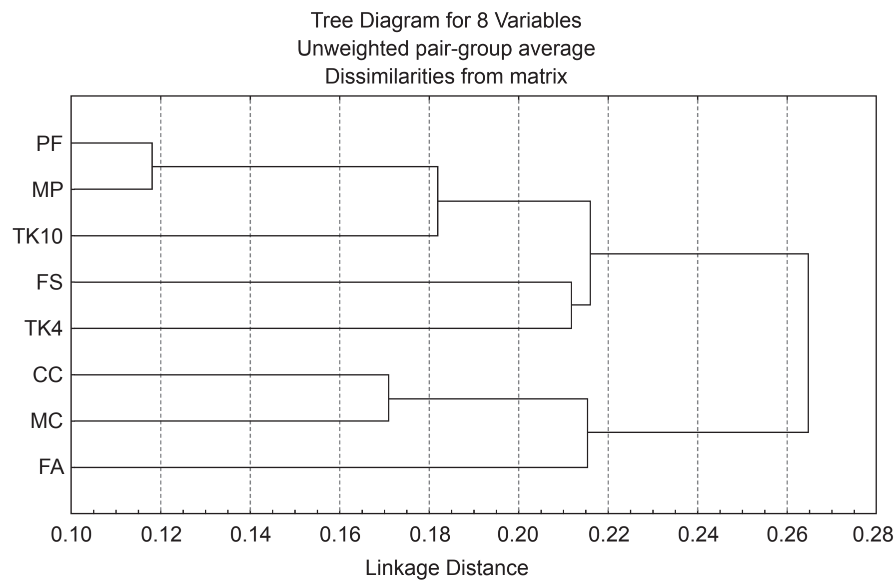

Fig. 4. Dendrogram showing similarities among investigated agroecosystems based on the Sorensen indexes listed in table 2. PF, primary forests; FS, secondary forests; MP, multi-species plantations; TK10, 10-yr-old teak plantations; TK4, 4-yr-old teak plantations; CC, cocoa plantations; FA, rural fallow fields; MC, mixed-crop fields.

Table 3. Sorensen indexes utilized in the dendrogram presented in figure 4 (PF, primary forests; FS, secondary forests; MP, multi-species plantations; TK10, 10-yr-old teak plantations; TK4, 4-yr-old teak plantations; CC, cocoa plantations; FA, rural fallow fields; MC, mixed-crop fields)

First sample	Second sample	Sorensen classic
PF	SF	0.811
PF	MP	0.882
PF	TK10	0.788
PF	TK4	0.733
PF	CC	0.722
PF	FA	0.778
PF	MC	0.769
SF	MP	0.811
SF	TK10	0.722
SF	TK4	0.788
SF	CC	0.718
SF	FA	0.718
SF	MC	0.762
MP	TK10	0.848
MP	TK4	0.867
MP	CC	0.778
MP	FA	0.722
MP	MC	0.769
TK10	TK4	0.759
TK10	CC	0.8
TK10	FA	0.629
TK10	MC	0.737
TK4	CC	0.75
TK4	FA	0.688
TK4	MC	0.686
CC	CC	0.789
CC	MC	0.829
FA	MC	0.78

DISCUSSION

Mixed-crop fields contained more individuals and families than did the other agroecosystems (Table 2), and according to the Shannon diversity index, mixed-crop fields were characterized by the highest species diversity. The highest abundance and diversity values were correlated with the highest habitat heterogeneity, with more-numerous ecological niches supporting insect development and their trophic requirements. Cultivated landscapes are highly heterogeneous and provide several types of habitats suitable for a great number of species (Jeanneret et al. 2003). Spatial and temporal distributions of suitable habitats are key factors in the biodiversity of cultivated landscapes. Consequently, in agroecosystems, biological processes and human decision-making

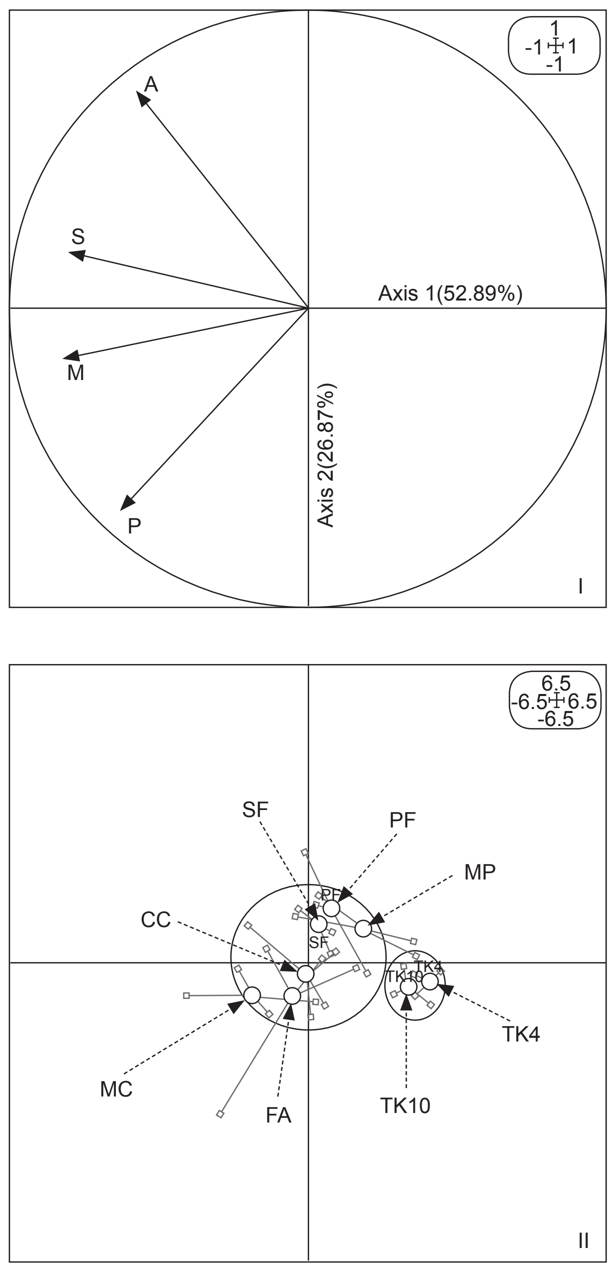

Fig. 5. Correlation circle I: (A, yellow aerial traps; S, yellow ground traps; M, Malaise traps; P, pitfall traps), II: star projection on the factorial plan (PF, primary forests; SF, secondary forests; MP, multi-species plantations; TK10, 10-yr-old teak plantations; TK4, 4-yr-old teak plantations; CC, cocoa plantations; FA, fallow fields; MC, mixed-crop fields).

processes interact to create complex, temporally and spatially dynamic entities (Jepsen et al. 2005). The habitat homogeneity of teak plantations can explain the lower abundance of beetles. The same trend was observed in multi-species plantations where habitat reconstitution was not total. The abundance of the microfauna increases with that of ligneous plants (Kouassi 1999). Trapping methods influenced the total beetle catch; the maximum height of traps used in this experiment was 2 m, and the traps did not reach the canopy in the forests and teak plantations where trees were much taller. The majority of insects in these habitats have a tendency to migrate toward the canopy to reach flowers. Therefore, if there was an absence of non-crop ligneous plants forming a sub-canopy, the results of the sampling method may have been biased for these particular agroecosystems by providing lower than expected levels of species diversity. Additional studies at the species level are needed to understand differences in species composition among the different agroecosystems and between primary and secondary forests.

The families Chrysomelidae, Staphylinidae, and Nitidulidae were represented by the highest numbers of individuals. Their distributions differed according to habitat. The Chrysomelidae was most numerous and better represented in primary and secondary forests. Staphylinids were well represented in mixed-crop fields and the Nitidulidae in cocoa plantations. The high number of the Nitidulidae in cocoa plantations can be explained by the presence of fallen fruit, the main food source for this group. As for the predatory Staphylinidae, the high number of individuals in mixed-crop fields is probably correlated with the higher number of prey species. The presence of beetles in each agroecosystem depends on their ecology, and numbers vary according to habitat. This was demonstrated by the test of which beetle abundances and diversities significantly differed among the agroecosystems. However, the various agroecosystems had some families and species in common. These similarities may have been due to the relatively close proximity of some of the agroecosystems and many of the sample sites in the grid being located at or near the transition area between differing habitats. Similarities in beetle abundances and diversities of many polyphagous species that favor disturbed habitats were further compounded by the ability to fly and therefore migrate to neighboring habitats in search of food, shelter, and mates. The presence of tourist and transitional species may depend on individual mobility (Moreno and Halffter 2001).

The capture method and the capacity of Malaise traps to intercept all flying beetles can explain the high number of individuals observed. Malaise traps are intercept traps, which allows sampling of insect fluxes between different habitats. High numbers of beetles were collected by Malaise traps in mixed-crop fields because this habitat was more accessible than the others. The yellow ground traps allowed detection of greater differences among beetle abundances in the different agroecosystems. Generally, the capture methods do not have the same capacity for collecting insects, and therefore insect studies in tropical habitats would benefit from the application of different trapping systems (Braet et al. 2000).

CONCLUSIONS

The results showed that some transformed ecosystems support abundant populations of beetles with diversities varying according to the land use type. Cultivated landscapes represented by cocoa plantations, mixed-crop fields, and rural fallow fields can be characterized by abundant beetle populations and high species diversity. Teak plantations and multi-species plantations are characterized by lower abundances. In less-perturbed ecosystems represented by primary and secondary forests, beetle abundances were low compared with cultivated landscapes. The families Nitidulidae, Staphylinidae, and Chrysomelidae were best represented in the majority of agroecosystems. Human activities had an impact on beetle abundance and diversity levels in these modified habitats. The yellow ground traps and Malaise traps provided particularly sensitive tools for studying the impacts of habitat change on beetle abundances. In the future, we will expand the scope of this study by defining beetle composition characteristics in these different ecosystems.

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