

Impact of rubber plantation on carabid beetle communities and species distribution in a changing tropical landscape (southern Yunnan, China)

Ling-Zeng Meng · Konrad Martin ·
Andreas Weigel · Jing-Xin Liu

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Abstract Carabid beetles (Coleoptera: Carabidae) have widely been used to assess biodiversity values of different habitats in cultivated landscapes, but rarely in the humid tropics. This study aimed to investigate effects of land use change on the carabid assemblages in a tributary valley of the Mekong River in tropical southern Yunnan, China. The study area includes habitats of traditional land use systems (rice production and shifting cultivation successions) and was dominated by natural forests until about 30 years ago. Since then, large areas of forest have been, and still are, successively transformed into commercial rubber monoculture plantations. In total, 102 species of Carabidae (including Cicindelinae) were recorded from 13 sites over different seasons, using pitfall traps, Malaise traps and aerial collectors in trees. Cluster analysis and indicator species analysis showed that three types of habitat (rice field fallows, early natural successions and natural forest)

possess a degree of uniqueness in species composition. Non-metric multidimensional scaling revealed that the environmental factors explaining 80% of the total variation in carabid assemblage composition are the degree of vegetational openness of a habitat and its plant species diversity. Rice field fallows had significantly higher numbers of species and individuals than any other type of habitat and are probably dominated by species originating from other regions. Carabid assemblages of young rubber plantations (5 and 8 years) were quantitatively similar to those of forests, but without species of significant indicator value. With increasing plantation age (20 and 40 years), the number of carabid species decreased. Increasing age and a further spatial expansion of rubber plantations at the expense of forest areas will have negative impacts on the native forest carabid assemblages with strongest effects on forest specialists and rare species.

Present Address:

L.-Z. Meng (✉) · K. Martin · J.-X. Liu
Agroecology in the Tropics and Subtropics (380b), University
of Hohenheim, 70593 Stuttgart, Germany
e-mail: mlz@xtbg.org.cn

K. Martin
e-mail: k.martin@uni-hohenheim.de

J.-X. Liu
e-mail: Jingxin.Liu@uni-hohenheim.de

L.-Z. Meng
Xishuangbanna Tropical Botanical Garden (XTBG),
The Chinese Academy of Sciences, Menglun,
Mengla 666303, Yunnan, China

A. Weigel
Rosalia Umweltmanagement, Am Schloßgarten 6,
07381 Wernburg, Germany
e-mail: rosalia@versanet.de

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Introduction

Carabid beetles (Coleoptera: Carabidae) have been widely used to assess biodiversity values of different habitats in cultivated landscapes usually composed of heterogeneous mosaics of various land uses. Most species are carnivorous and actively hunt for any small invertebrate prey they can overpower and some species are polyphagous which feed the small seeds of herbaceous plants (Honek et al. 2003). Specific aspects of carabid beetle diversity and distribution include e.g. spatio-temporal changes across gradients of vegetation, land use intensification or disturbance (Aviron et al. 2005; Gobbi and Fontaneto 2008; Gu et al. 2008;

Roughley et al. 2006; Yu et al. 2007), effects of habitat fragmentation and isolation (Fujita et al. 2008; Wamser et al. 2010), and effects of land management and cropping systems (Eyre et al. 2009; O'Rourke et al. 2008), grasslands (Purtauf et al. 2004), forests and forest plantations (Fuller et al. 2008; Taboada et al. 2008; Yu et al. 2008). Conclusions drawn from those studies are that most carabid species can be subdivided in open land and forest species, with specialists and generalists in each group. Furthermore, increasing intensification and disturbance in cultivated landscapes tends to reduce forest specialist carabids and to homogenize the beetle assemblages between the habitat types. Nearly all studies were conducted in temperate or subtropical regions, where the original vegetation has disappeared or been strongly modified in the course of a usually long history of land cultivation. Very little research has been conducted on the effects of land use change on carabid assemblages in relatively young cultivated landscapes of tropical rainforest regions (but see Goehring et al. 2002 and Gormley et al. 2007 for Costa Rica, and Rainio and Niemelä 2006 for Madagascar).

In this study, we investigate the carabid assemblages of the major land use types in a tropical landscape of southern Yunnan, China. The region is part of the 'Indo-Burma hotspot', one of the 34 global hotspots exceptionally rich in biodiversity (Biodiversity Hotspots 2007). The study area represents a tributary valley of the Mekong River. There, traditional land use systems are irrigated rice fields along the river courses and shifting cultivation systems on the slopes, but the largest proportion of the land area was covered with primary and secondary forest until about 30 years ago. Since then, large areas of forest have been, and still are, successively transformed into commercial rubber monoculture plantations of different age. This pattern is representative of the development of tropical southern Yunnan. Detailed data from a typical subregion showed that between 1988 and 2006, rubber plantations increased from 12% of the total land cover to 46%, whereas forested areas dropped from 49 to 28% (Hu et al. 2008). Tropical seasonal rainforest was the type of land most affected by the expansion of rubber plantations (Li et al. 2007).

Methods

Study area and sampling sites

The study was conducted in the Naban river valley (ca. 11,000 ha), within the area of the Naban River Watershed National Nature Reserve (NRWNNR) in Xishuangbanna, southern Yunnan province, south-west China (22° 10' N and 100° 38' E). The region represents the northernmost

part of the humid tropics in Asia with a climate influenced by Monsoon and three distinct seasons: cool-dry (October–January, with the lowest monthly temperature of 15°C in December), hot-dry (February–April, with the highest monthly temperature of 25°C in April) and a rainy season (May–September) with most of the mean annual precipitation of almost 1,600 mm. The natural vegetation of the study region is tropical rainforest, falling into different types of evergreen and seasonal forests related to topography and elevation (Cao et al. 2006; Lü et al. 2010). Secondary and primary forest sites and fragments are still widespread in the study area, but most cultivated land is covered by plantations of rubber (*Hevea brasiliensis*). The remaining land use types are mainly rice fields in the valley bottoms and other crops around the small villages, and grassland and shrubland successions. A map of the current land use (Fig. 1) was derived from IKONOS satellite imagery (acquired on November 16 and December 2, 2007) via supervised classification using ERDAS Imagine software (Berkhoff et al. 2009). To represent the most typical land-use types of this landscape, 13 sites including forest plots, rubber plantations and different types of open land (Table 1) were selected for recording the Carabidae, including the subfamily of tiger beetles (Cicindelinae).

Field methods

Beetle sampling was carried out by using a combined trap system including pitfall traps and Malaise traps (Townes 1962) at all sites, and aerial collectors in the canopy area of trees in forests and in rubber plantations. Pitfall traps were plastic pots with a diameter of 8.5 cm and a depth of 13 cm buried flush to the soil surface, one-third filled with 10% formalin solution. At each site, five pitfall traps were arranged at a distance of ca. 3 m from each other around a Malaise trap. Aerial collectors were constructed of two pieces of transparent plastic plates (50 × 30 cm, height × width) which were arranged crosswise and fixed upon a red plastic bowl of 30 cm in diameter. These traps were installed on canopy tree branches using ropes. The collecting bottles of the Malaise traps and the bowls of the aerial collectors were filled with a mixture of liquid of blue coloured anti-freeze (ethanol-glycol).

Traps were installed in different seasonal periods covering (a) the beginning of the rainy season (May–July 2008), (b) the beginning of the cool-dry season (September–November 2008), and (c) the transition period from the hot-dry to the rainy season (March–June 2009). All traps were emptied every 10 days during the collecting periods (with few exceptions where traps were destroyed or collection was impossible due to heavy rains). The beetle specimens were preserved in 70% ethanol for further identification to the lowest possible taxonomic level. Data

Fig. 1 Major land use types along the Naban River valley within the boundaries of the Naban River Watershed National Nature Reserve, and locations of the study sites according to Table 1

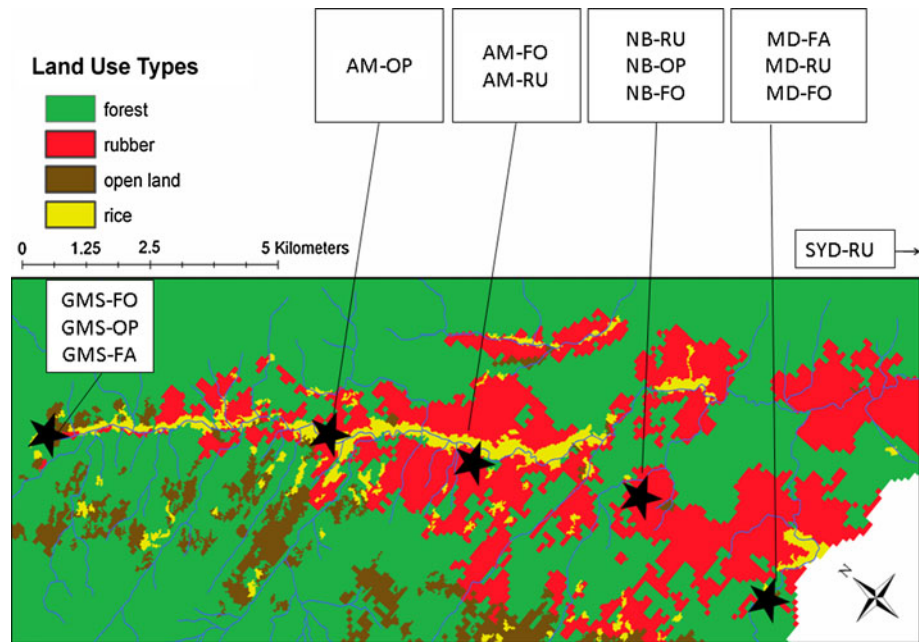


Table 1 Habitat characteristics of the 13 sampling sites and the environmental variables used in the NMS analysis

Study site (Code)	No. of plant species						GroCov (%)	CanCov (%)	SucAge (years)	VegHei (m)	Land use
	Plant	Grass	Forb	Liana	Shrub	Tree					
Forest (MD-FO)	91	7	14	10	26	34	50	95	80	30.3	3
Forest (NB-FO)	119	2	17	15	34	51	68	90	70	33.4	3
Forest (AM-FO)	93	10	14	10	24	35	73	95	80	21.5	3
Forest (GMS-FO)	96	18	17	10	18	33	75	85	60	28.5	3
Rubber (MD-RU)	53	16	13	5	6	13	30	75	5	10.1	2
Rubber (NB-RU)	49	12	21	2	5	9	21	87	8	11.7	2
Rubber (AM-RU)	45	10	10	4	11	10	12	94	20	20	2
Rubber (SYD-RU)	18	5	7	1	3	2	5	95	40	30	2
Clear fell (NB-OP)	45	8	18	3	12	6	85	1	2	2.5	4
Grassland (AM-OP)	57	18	18	3	12	6	75	1	5	1.2	4
Shrubland (GMS-OP)	61	20	17	3	14	7	90	1	25	1.2	4
Rice fallow (MD-FA)	53	16	35	0	1	1	95	1	1	0.7	1
Rice fallow (GMS-FA)	60	22	38	0	0	1	97	1	1	0.6	1

Total number of vascular plant species (Plant) and species numbers of different life forms; percentage of ground vegetation cover (GroCov) and canopy cover (CanCov); the successional age of the site or age of the trees (SucAge); vegetation height (VegHei) and four categories of land use

analyses are based on numbers of species and individuals combined from all traps and trap types per site and the total counts from all collecting periods. Voucher specimen of the collected beetles are kept at the National Zoological Museum of China, Institute of Zoology, CAS, Beijing.

Vascular plant species inventories from each of the 13 trap sites were recorded in March 2009. At the four natural forest sites, four 20 × 20 m² plots were established around the trap locations to record the numbers of tree and liana species. The other plant species (representing the ground-cover vegetation <2 m) in the forest plots were recorded from four 5 × 5 m² subplots within each of the four large

plots. Total species numbers of the four small and the four large plots were used for further calculations. In the other sites, records from all four 5 × 5 m² plots per site provided the plant species numbers used for calculations. Voucher specimens of the recorded and identified plant species were deposited at the Herbarium of the Xishuangbanna Tropical Botanical Garden (XTBG), CAS, Yunnan, China.

Data analyses

Cluster analyses were performed to identify quantitatively similar groups of carabid assemblages among the different

sites and habitats. We used the Morisita index of similarity (Morisita 1959), being recommended as the best overall similarity measure in community analysis (Wolda 1981). Among the algorithms for hierarchical clustering, we selected the unweighted pair-group method using averages (UPGMA) which is conventionally used in ecology (James and McCulloch 1990; Wolda 1981). One-way ANOSIM (analysis of similarities) global tests were then applied to test for differences between subgroups produced by the cluster analysis. Differences in total species numbers and abundances of carabids between the subgroups were compared by the Mann–Whitney *U*-test using Minitab 15.0 software (Minitab Inc. State College PA, USA). This non-parametric test was applied because the assumptions of homogeneity of variances and normality (tested with the Shapiro–Wilk normality test) were not met according to Zar (1996).

Non-metric multidimensional scaling (NMS; Kruskal 1964) using the Bray–Curtis index for abundance data was applied to display and test for differences in carabid assemblage composition across the habitat types. This ordination scores was performed with PC-ORD software (McCune and Mefford 2006) with the following parameters employed in the NMS procedure: Sorensen distance measure; a maximum number of 500 iterations; random starting coordinates; 100 runs with real data; step down in dimensionality (initial step length = 0.2); 100 runs with randomized data. A total of 11 vegetation and land use variables after log transformed were included in the NMS analysis to test their effects on the carabid assemblages. Six variables refer to plant species richness, including the total number of vascular plant species per site and the species numbers of different life forms, i.e. grasses, forbs (non-woody plants other than grasses), trees and lianas. The remaining variables are the degree of tree canopy cover and the degree of ground vegetation cover, the maximum vegetation height, the successional age of the study site (years after establishment of the present vegetation or age of the trees), and the discrimination between four categories of land use type, represented by rice field fallows, early successions (forest clear fell, grassland, scanty shrubland), rubber plantation and natural forest (Table 1). Correlations between the ordination and the environmental variables were calculated with the Pearson coefficient. Indicator Species Analysis based on the combined values of relative abundance and relative frequency of species (McCune and Grace 2002) was used to identify carabid species affiliated with specific land use types. The indicator value of each of the recorded species was calculated with PC-ORD software (McCune and Mefford 2006) using 4,999 runs in a Monte Carlo test considering values at $P < 0.05$.

Results

A total number of 102 carabid species (including 16 species of Cicindelinae) and 1,649 individuals were recorded across all study sites and recording periods (“Appendix”). The cluster analysis dendrogram based on the quantitative similarities of the carabid assemblages is shown in Fig. 2. As supported by global one-way ANOSIM tests, meaningful differences between assemblages occurred at a similarity of 0.5 and generated 4 subgroups (global $R = 0.94$; $P < 0.0001$). Subgroup 1 is represented by three sites, including the oldest rubber plantation (40 years), a forest clear fell site and an adjacent forest fragment. Subgroup 2 includes the three younger rubber plantations (5, 8 and 20 years) and three forest sites. Subgroup 3 represents two early succession sites (grassland and shrubland), and subgroup 4 is formed by the two rice field fallows.

Figure 3 shows the differences in (a) numbers of species and (b) numbers of individuals of carabids between the four subgroups generated by cluster analysis. Subgroups 1, 2 and 3 have the lowest numbers of both species and individual numbers which were not significantly different from each other. Subgroup 4 had significantly higher numbers in all comparisons ($P < 0.05$; Mann–Whitney *U*-test).

Two axes were recommended by the NMS ordination of carabid assemblages (Fig. 4) which together explain 80% of the total variance in the data set (Axis 1 = 48%, Axis 2 = 32%) at a final stress of 13.5. The final instability was

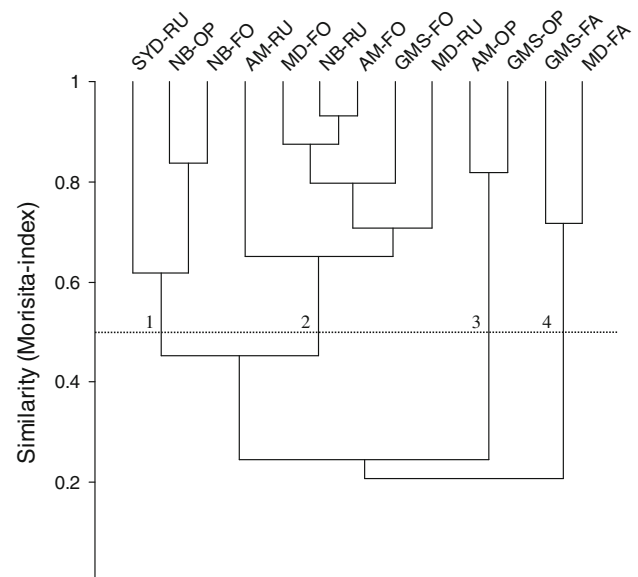


Fig. 2 Quantitative similarity cluster analysis of the carabid communities at the sampling localities (site codes see Table 1), generated from the Morisita-index using UPGMA. The dendrogram shows 4 subgroups at similarity levels >0.5 , indicated by the dashed line

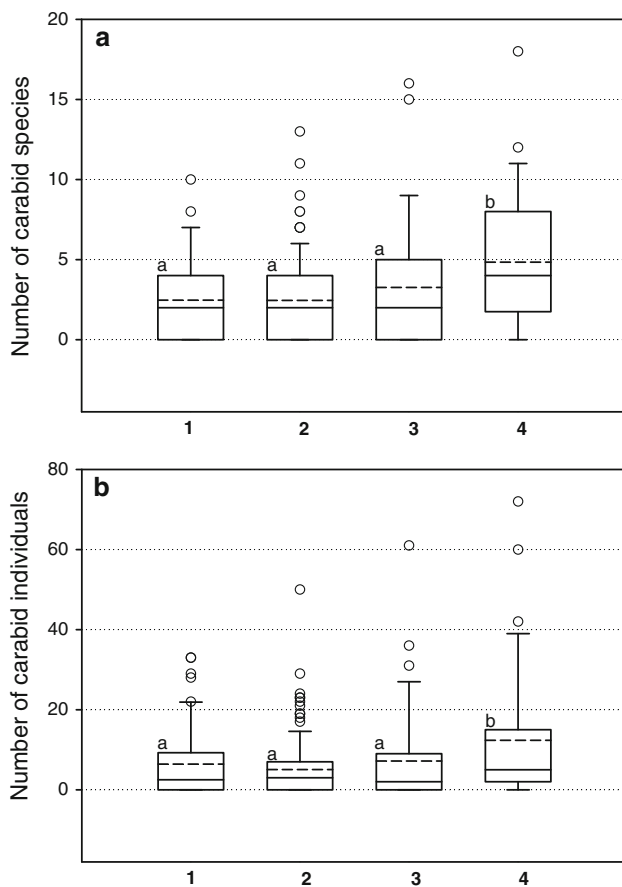


Fig. 3 Number of species (a) and number of individuals (b) of carabids in the four subgroups produced by cluster analysis (1–4, see Fig. 2). Box and whisker plots illustrate the 5, 25, 50 (median), 75, and 95th percentiles, and the means as the dashed line. Different letters indicate significant differences ($P < 0.05$; Mann–Whitney U-Test)

0.00001 with 500 iterations. All environmental variables except the number of shrub species and land use category showed significant effects at $P < 0.05$ (Pearson correlation coefficient). Axis 1 represents a gradient along the successional development with canopy-covered habitats (forests and rubber plantations) on the negative side and open land (rice field fallows and early successions) on the positive side. Axis 2 shows a positive correlation with total plant species richness per site. Thus, the environmental factors explaining totally 80% of the variation in carabid assemblage composition are the degree of vegetational openness of a habitat and its plant species diversity. A total of 11 ground beetle species with indicator values at $P < 0.05$ were identified (see Appendix for species indication). Of these, 7 species were specialists of rice field fallows including *Acupalpus* sp. 2, *Aephnidius* sp., *Chlaenius laetiussculus*, Harpalini Gen. sp. 4, *Platymetopus* sp., *Stenolophus quinquepustulatus* and *Stenolophus* sp. 3, two species were specialists of early successions (both

representing Cicindelinae) including *Calochroa interruptofasciata* and *Lophyra lineifrons*, and two species were natural forest specialists including *Orthogonius* sp. 2 and *Pheropsophus* cf. *beckeri*. No species were significantly affiliated with rubber plantations.

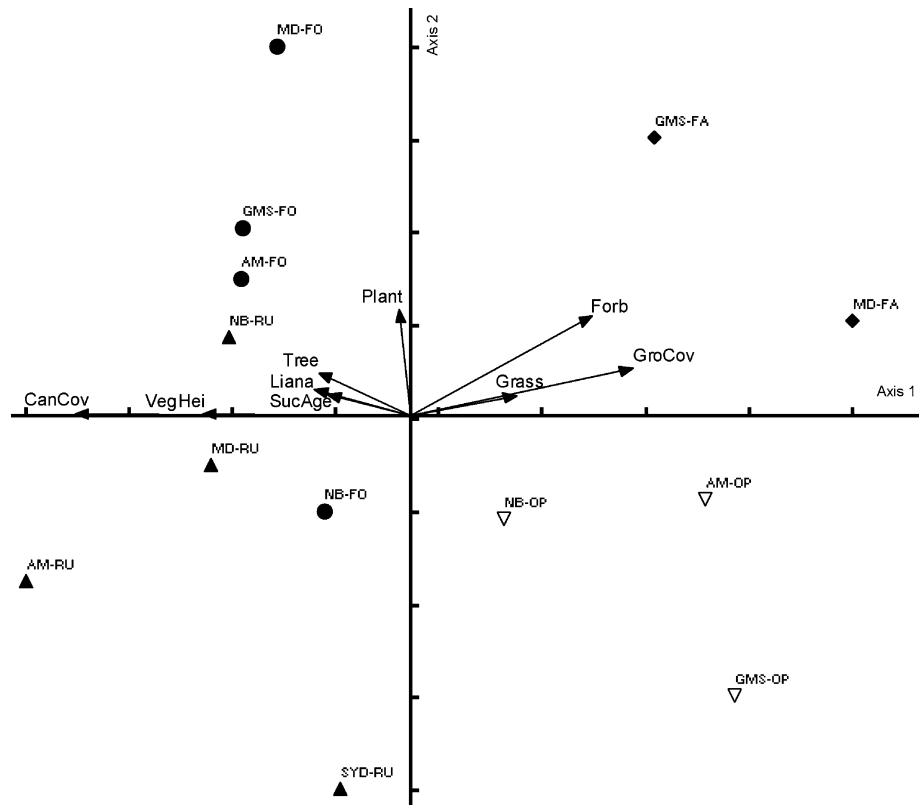
Discussion

The overall results regarding the carabid assemblage patterns of the valley landscape indicates that three land-use types (rice field fallows, early successions and natural forest) possess a degree of uniqueness in species composition, each characterized by species with significant indicator values. Only 11 habitat specialist species were identified out of totally 102 recorded species. The numbers of specialists might indeed be higher if we used the additional analysis of estimated species number through Chao estimator, because most of the species were only represented by few individuals which were not enough to show statistically significant results. For example, from the 59 species recorded from forests, 14 species with numbers between one and 6 individuals were only found there. Although they were not denoted as indicator species, there might be forest specialists among them which are merely rare.

The highest numbers of total species and individuals were recorded from the rice field fallows (subgroup 4 in the cluster analysis, Figs. 2 and 3). Since the natural vegetation in the study region is tropical forest, it can be concluded that the 7 specialist species and certainly others originate from naturally open habitat types of other regions. This can also be assumed for the carabid species typical of the grassland and shrubland in the study area. These habitats are characterized by the highest abundances of most of the ground-dwelling Cicindelinae in an assemblage group distinct from other habitats (subgroup 3 in the cluster analysis, Fig. 2). The youngest rubber plantations with open canopy (5 and 8 years old) contain carabid species which were also recorded from other habitat types, but their quantitative assemblage composition show highest similarity to that of the forests (subgroup 2 in the cluster analysis, Fig. 2). The 20 year old rubber plantation with a closed canopy belongs to the same subgroup but has the greatest community distance from the other sites. The 40 year old rubber plantation falls into an assemblage group characterized by highly degraded or disturbed habitats of original forest, along with a forest clear fell and a small forest fragment (subgroup 1 in the cluster analysis, Fig. 2). Most carabid species of this group are ubiquitous species which occur in both open land and closed canopy habitats.

It might be expected that vegetation openness to be important for ground surface active predatory carabids,

Fig. 4 NMS ordination of carabid communities at the 13 sample sites: (filled triangle) rubber plantation; (empty square) grassland and shrubland; (empty square) rice field fallow; (filled circle) forest. Variables with a Pearson correlation coefficient at $P < 0.05$ are shown. Cumulative variation in the original dataset explained by ordination is 80% (Axis 1 = 47%, Axis 2 = 33%, Final stress = 13.5, Final instability = 0.00001)



while plant species diversity might be expected to be important for seed-feeding *Harpalines* species. Genus including *Acupalpus* and *Chlaenius* species like wet and marshy locations and hence associated more with habitat of rice fallow than forest. *Harpalus* sp. are very small seed-feeders relying strongly on the seed supply from different weeds and therefore favour openness of habitat and were mostly found in the pastures (Gu et al. 2008). *Pheropsophus* species are predators and known to be forest specialists to predate the eggs of mole cricket.

Overall, the present land use types of the study area show a dynamic pattern of closed and open habitats with distinct and characteristic carabid assemblages, except those of the rubber plantations. Most of the rubber plantations in the study area are less than 20 years old, but will reach an age of about 40 years before the latex productivity declines. Then, the plantations will be clear felled for starting a new plantation cycle with young trees. Although the carabid assemblages of young rubber plantations are similar to those of the forest sites, the results also indicate that rubber plantations do not provide alternative habitats for the species indicated as being forest specialists. Young plantations are temporarily suitable for many carabid species, probably because they provide a ground cover vegetation of relatively high density and diversity in addition to the presence of a canopy. However, with increasing plantation age and the close of the canopy, the ground cover

vegetation is shaded out and disappears, as shown by the 40 year old rubber plantation with an extremely low plant species richness (Table 1). This may explain that the lowest total carabid species richness of all habitat categories was recorded from the 20–40 year old rubber plantations with closed canopies (25 species) compared to the 5–8 year old plantations with open canopies (34 species) and natural forest (59 species, see Appendix).

The question of how non-indigenous tree plantations, such as conifers or *Eucalyptus*, affect the diversity of and composition of carabid assemblages has been addressed in other landscapes. It was generally confirmed that carabid assemblage composition changes with increasing plantation age, which is usually related to a reduction of open land species (Jukes et al. 2001; Karen et al. 2008; Pawson et al. 2009). However, no overall conclusions can be drawn on the value of mature tree plantation stands for the conservation of carabids originating from natural forests. There are studies showing a reduced carabid species richness in plantations compared to forests (da Silva et al. 2008; Fahy and Gormally 1998; Magura et al. 2003) or a lower number of forest specialist species (Fuller et al. 2008). On the other hand, it was shown that carabid beetle assemblages of mature plantations do not significantly differ from those of natural or semi-natural forest (Elek et al. 2010; Karen et al. 2008; Martinez et al. 2009), indicating that the establishment of tree plantations will not

lead to a reduced carabid diversity at the landscape scale. Various environmental factors may account for such differences. Although the degree of canopy cover proved to be an important factor of the habitat suitability for forest carabid species, the structure and diversity of the ground cover vegetation is also closely related to the species richness and abundance of carabids, as shown in the present study and in others (Karen et al. 2008; Oxbridge et al. 2010; Pawson et al. 2009; Yu et al. 2008). However, it is difficult to distinguish between the effects of tree species composition and spatial heterogeneity on the species richness of the ground vegetation and ultimately the carabid species richness in different forest and plantation types (Taboada et al. 2010). Another factor influencing the differences in carabid composition between forest and plantations in a given landscape can be the habitat quality of forest plots, indicated by the degree of disturbance, fragmentation or size. For example, Fujita et al. (2008) found that the richness of forest carabid species markedly decreased with the reduction of area of forest fragments. The poor habitat quality of patchy native forest remnants enclosed by plantations was assumed to be the main factor explaining the high similarity in carabid diversity of the two habitat types in the study of Martinez et al. (2009).

Conclusions

To assess the effects of rubber plantations on the diversity and distribution of carabid species in the study region, temporal and spatial changes need to be considered. Currently most of the rubber plantations represent young stages of development which provide a transient habitat for forest generalists from the neighbouring forest areas and

for ubiquitous species. With increasing plantation age, however, habitat quality decreases for all species. A further expansion of rubber cultivation will finally result in large areas of mature rubber plantations with negative impacts on the native forest species populations and strongest effects on forest specialists and rare species. Because rubber cultivation largely proceeds at the expense of forest areas and not of cultivated land, the carabid assemblages of open habitats will be less affected by this scenario. It is therefore essential to protect natural forest areas as a pool for forest carabid species. Effects of rubber plantations could then be mitigated by a management of the rotation cycles that allows the steady presence of young plantation stages with a ground cover vegetation that can serve as a temporary habitat for carabid species.

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Appendix

See Table 2 below.

Table 2 List of carabid species and numbers of individuals recorded from the 13 study sites compiled by habitat type

Species	Forest	Rubber (5–8 years)	Rubber (20–40 years)	Grass, shrub	Rice fallow
<i>Acupalpus</i> sp. 1	0	0	0	8	1
<i>Acupalpus</i> sp. 2 ^R	0	0	0	0	2
<i>Acupalpus</i> sp. 3	0	0	1	0	0
<i>Aephnedius</i> sp. ^R	0	0	0	0	3
Agonini Gen. sp. 1	1	1	0	0	0
Agonini Gen. sp. 2	2	0	0	0	0
Agonini Gen. sp. 2	8	0	2	1	2
<i>Amblystomus</i> sp. 1	1	0	0	0	0
<i>Amblystomus</i> sp. 2	0	0	0	0	2
<i>Amblystomus</i> sp. 3	0	0	0	1	25
<i>Amblops piceus</i> (Andrewes 1931)	2	0	0	0	0
<i>Anisodactylus karennius</i> (Bates 1892)	0	0	0	0	1

Table 2 continued

Species	Forest	Rubber (5–8 years)	Rubber (20–40 years)	Grass, shrub	Rice fallow
<i>Badister (Baudia) sp.</i>	0	0	0	0	1
<i>Bembidion sp.</i>	3	0	0	0	1
Bradycellini Gen. sp.	0	0	0	1	2
<i>Calleida klapperichi</i> (Jedlička 1963)	6	0	0	0	0
<i>Calleida sp.</i>	0	1	0	0	0
<i>Callistoides caeruleiceps</i> (Bates 1892)	0	0	0	1	1
<i>Callistomimus quadricolor</i> (Putzeys 1877)	0	0	0	2	0
<i>Casnoidea indica</i> (Thunberg 1784)	1	0	0	0	0
<i>Catascopus cf. facialis</i> (Wiedemann 1819)	7	1	2	1	0
<i>Catascopus sp.</i>	1	0	0	0	0
<i>Chlaenius costiger</i> (LaFerte-Senectere 1856)	2	3	0	1	2
<i>Chlaenius circumdatus</i> (Brulle 1835)	0	0	0	1	1
<i>Chlaenius laetiusculus</i> -group ^R	0	0	0	0	2
<i>Chlaenius bimaculatus</i> (Dejean 1826)	1	0	0	3	2
<i>Chlaenius cambodiensis</i> (Bates 1889)	0	0	0	6	3
<i>Clivina sp.</i>	0	0	3	1	1
<i>Coptodera sp.</i>	3	0	0	0	0
<i>Cymindis sp.</i>	1	1	0	3	0
<i>Dicranoncus quadridens</i> (Motschulsky 1859)	0	1	0	0	0
<i>Dioryche sp.</i>	1	0	1	0	2
<i>Dromiini</i> Gen. sp.	1	0	0	0	0
<i>Dromius (Klepterus) sp.</i>	0	1	0	0	0
<i>Dyschirius sp.</i>	0	0	6	0	2
<i>Egadroma sp.</i>	10	3	3	6	7
<i>Elaphropus poecilopterus</i> (Bates 1873)	0	0	0	0	1
Gen. sp. (Lebiini?)	1	0	0	0	0
Harpalini Gen. sp.	0	2	0	0	1
Harpalini Gen. sp. 1	0	0	0	1	1
Harpalini Gen. sp. 2	0	0	0	0	3
Harpalini Gen. sp. 3	3	1	0	7	3
<u>Harpalini Gen. sp. 4^R</u>	2	2	0	2	6
<i>Harpalus sp. 1</i>	0	1	2	20	10
<i>Harpalus sp. 2</i>	0	0	0	2	1
<i>Harpalus sp. 3</i>	2	1	0	22	15
<i>Holcoderus ? sp.</i>	1	0	0	0	0
<i>Holosoma cf. opacum</i> (Semenov 1889)	3	0	0	1	0
<i>Lebia sp. 1</i>	1	0	0	1	0
<i>Lebia sp. 2</i>	1	1	0	0	0
Lebiini Gen. sp.	4	0	0	0	1
<i>Macrocheilus tripustulatus</i> (Dejean 1825)	0	2	0	1	0
<i>Macrocheilus chaudiiri</i> (Andrewes 1919)	2	1	0	0	0
<i>Microlestes sp.</i>	1	0	0	1	4
Oodini Gen. sp. 1	1	0	1	0	0
Oodini Gen. sp. 2	3	1	0	0	1
Oodini Gen. sp. 3	0	0	0	1	0
<i>Orthogonius sp. 1</i>	92	25	3	15	50
<u><i>Orthogonius sp. 2^F</i></u>	119	27	7	43	11

Table 2 continued

Species	Forest	Rubber (5–8 years)	Rubber (20–40 years)	Grass, shrub	Rice fallow
<i>Orthogonius</i> sp. 3	24	3	7	5	9
<i>Orthogonius</i> sp. 4	41	11	7	7	7
<i>Orthogonius</i> sp. 5	8	3	1	5	1
<i>Oxycentrus</i> sp.	0	1	2	7	0
<i>Peliocyphas</i> sp.	4	0	1	0	0
<i>Pentagonica</i> sp.	15	16	3	11	9
Perigonini gen. spec.	2	0	0	0	0
<u><i>Pheropsophus</i> cf. <i>beckeri</i> (Jedlička 1930)^F</u>	24	0	0	0	1
<i>Pheropsophus</i> cf. <i>javanus</i> (Dejean 1825)	0	0	0	0	3
<u><i>Platymetopus</i> sp.^R</u>	0	0	2	0	3
Platynini Gen. sp. 1	0	2	0	0	3
Platynini Gen. sp. 2	0	0	0	1	2
Platynini Gen. sp. 3	1	0	0	0	1
Platynini Gen. sp. 4	4	0	1	1	0
<i>Platynus</i> sp.	3	0	1	0	1
<i>Harpalus</i> (<i>Pseudoophonus</i>) <i>cyanelus</i> (Kraatz 1874)	0	0	0	1	5
Pterostichini Gen. sp. 1	1	0	0	0	0
Pterostichini Gen. sp. 2	0	1	0	0	0
Sphrodrini Gen. sp.	4	0	0	0	0
Stenolophini Gen. sp. 1	0	0	0	0	1
Stenolophini Gen. sp. 2	0	0	0	0	1
<u><i>Stenolophus</i> <i>quinquepustulatus</i> (Wiedem. 1823)^R</u>	1	1	0	2	139
<i>Stenolophus</i> sp. 2	0	0	0	1	1
<u><i>Stenolophus</i> sp. 3^R</u>	5	1	1	0	31
<i>Syntomus</i> sp.	1	0	0	0	1
<i>Trichotichnus</i> sp.	5	2	1	2	2
<i>Trigonotoma</i> sp.	0	0	0	1	1
Cicindelinae					
<i>Callytron andersonii</i> (Gestro 1889)	2	0	0	6	7
<i>Calochroa elegantula</i> (Dokhtoureff 1882)	16	7	29	46	10
<u><i>Calochroa interruptofasciata</i> (Schmidt-Go. 1846)^G</u>	3	0	0	30	0
<i>Calochroa salvazi</i> (Fleutiaux 1919)	1	0	0	12	6
<i>Cosmodela virgula</i> (Fleutiaux 1893)	0	0	0	2	1
<i>Cylindera holosericea</i> (Fabricius 1801)	0	0	0	3	0
<i>Cylindera kaleea</i> (Bates 1863)	1	1	0	18	24
<i>Cylindera spinolae</i> (Gestro 1889)	18	4	4	24	20
<i>Cylindera viduata</i> (Fabricius 1801)	0	0	0	3	0
<i>Heptodonta eugenia</i> (Chaudoir 1865)	5	1	0	5	1
<i>Lophyra striolata</i> (Illiger 1800)	0	0	0	1	0
<u><i>Lophyra lineifrons</i> (Chaudoir 1865)^G</u>	6	1	4	108	12
<i>Myriochila sinica</i> (Fleutiaux 1889)	0	0	0	5	0
<i>Neocollyris linearis</i> (Schmidt-Goebel 1846)	2	0	0	2	2
<i>Therates pseudorugifer</i> Sawada & Wiesner 1999	1	0	0	0	0
<i>Tricondyla mellyi</i> (Chaudoir 1850)	1	0	0	0	1
Number of species per habitat type	59	34	25	53	64

The Cicindelinae are listed separately. Species with indicator species values at $P < 0.05$ are *underlined*, and affiliation with habitat type is indicated by *superscript letters* (*F* forest, *R* rice field fallow, *G* grassland and shrubland)

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