FACULTY OF AGRICULTURAL SCIENCES

(Dr. sc. agr.)

Institute of Plant Production and Agroecology in the Tropics and Subtropics

University of Hohenheim

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Biodiversity and arthropod abundance in the upland of Leyte, Philippines

Dissertation

Submitted in fulfilment of the requirements for the degree "Doktor der Agrarwissenschaften"
(Dr.sc.agr. / Ph.D. in Agricultural Sciences)

to the

Faculty of Agricultural Sciences

presented by

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München

2005

This thesis was accepted as a doctoral dissertation in the fulfilment of the requirements for the degree “Doktor der Agrarwissenschaften” by the Faculty Agricultural Sciences at the University of Hohenheim, on 23.05. 2005.

Date of oral examination: 15. June 2005

Examination Commitee

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1. Introduction

In the humid tropics, the loss of the natural vegetation means the reduction of primary forest area due to commercial and illegal logging activities as well as slash-and-burn agriculture. Deforestation in tropical south-east Asia is the most rapid (Laurance 1999), reaching 1.6% between 1982 and 1990 compared to 0.9% in the rest of the tropics (Groombridge 1992). Total forest area in insular south-east Asia declined by more than 16 million ha during the 1990s, with an annual loss rate of 1.2% (FAO 2001). One of the highest deforestation rates is stated for the Philippines, with a loss of 30,350ha per year in the last decade (Kincaid 2002). Satellite images indicate a left forest cover of 17.8%; whereby 9.3% are secondary forest and only 8.6% are still natural forest cover (Geoanalytics 2003).

Population density in the Philippines was reported to be 251 persons/km² in 2000 (World Bank 2000). Scarcity of arable land and lack of income possibilities forces people to move up to remote areas by practicing slash-and-burn agriculture to maintain their livelihood. Thus even the last natural forests at the higher, mountainous elevations are affected.

The well known cost of the decline of natural habitats is the loss in diversity of fauna and flora and consequently also in ecosystem services and interactions, thus destabilizing the system and finally leading to degradation. Numerous studies focus on the especially high diversity of tropical forests, its richness in components and structure and the dependent specialisation of organisms and species on the specific habitats provided.

Erwin (1982) estimated the richness of coleoptera and other arthropod species within one hectare of tropical forest in Panama being more than 41,000. This figure is based on data of canopy insects collected by fogging methods and estimates of tropical plant host specificity. Basset et al. (1992) studied the abundance and stratification of foliage arthropods in a lowland rainforest of Cameroon, discussing possible reasons for the higher species richness in the canopy samples compared to samples obtained in the shrub layer. Novotny et al. (1997) focused on the diversity of insect herbivores in a tropical forest in Papua New Guinea. Herren (1998) discussed the importance of arthropod diversity for global environmental and food security, especially concerning the African tropics and here the arthropod provided services like the regulation of pests by predation and parasitism, their serving as food source for birds, amphibians, fishes and reptiles as well as in some regions also for human beings. Further mentioned are pollination, the organizing influence of insects in tropical forests through their role as herbivores and seed predators and also their contribution to maintain soil dynamics by litter- and dung composition, nitrogen mineralization and soil perturbation. Herren (1998) also points out the role of insects as early indicators, responding to environmental changes, before these become obvious. It is concluded, that much more research on arthropods is necessary for understanding the ecosystems on which humans rely on for their food production and living.

Sittenfeld et al. (1999) described the effort of several organisations in Costa Rica in using insects and other arthropods in biodiversity prospecting. In Odengaard (2000) the high diversity of tropical plant species is discussed in relation to arthropod species richness, concluding that data sets are still to few to provide global information about relations of plant and arthropod species richness. Novotny & Basset (2000) examined the host specificity, taxonomic composition and feeding guild of rare species in herbivore communities in New Guinea lowland rainforest and found, that these rare species are important and should not be excluded from community studies. Kitching et al. (2001) compared the arthropod biodiversity of four tropical rainforest areas in Australia and Borneo in order to contribute to the identification of general ecological patterns for rainforests. Their results confirm the hypothesis that there is a structural constancy in the abundance of arthropods of different groups across sites as sampled by a variety of sampling methods, leading to the assumption, that the composition of arthropod assemblages in forests of similar climate and other characteristics but different biogeographical regions may be similar at the family level and higher.

Latest the plant diversity in tropical forests and the mechanisms of species coexistence were reviewed by Wright (2002). He found that niche differences, Janzen-Connell effects (host specific pests reduce recruitment near reproductive adults), and negative density dependence occur over larger spatial scales among the more abundant species and regulate their populations. Also numerous studies deal with the consequences of tropical disturbance and fragmentation for flora and fauna. Sayer & Withmore (1991) described tropical moist forest destruction and species extinction by comparing destruction rates from all over the tropics. The rate of forest destruction predicted by the FAO for 1981-85 has been exceeded in all countries.

Turner (1996) in his review showed, that nearly all cases of tropical forest fragmentation led to a local loss of species, concerning vertebrates as well as invertebrates. Carvalho & Vasconcelos (1999) examined the effect of forest fragmentation on litter dwelling ants in the central Amazon. Their results suggest that edge and isolation effects both play a role in structuring ant communities in forest remnants, by showing greater species richness and nest density of ants in continuous forest than in fragments. Mesquita et al. (1999) dealt with the capacity of different regrowth forests to buffer edge effects on Amazonian forest fragments, and found significant influence by the structure of the surrounding vegetation on edge-related tree mortality. Laurance et al. (2000) also worked in the Amazonian forest and examined the effects of forest loss and fragmentation in the view of implications on wildlife conservation.

So far, only few studies focus on the biodiversity of cleared and converted land in the tropics, although the percentage cover of these areas outnumbers by far that one of the natural forests. In contrast to tropical areas, there are already many studies referring to the diversity, functions and interactions in the agricultural environment in temperate regions.

Duelli & Obrist (1998) for example calculated the correlation of species numbers of taxonomic groups with species numbers of flowering plants in order to define the best correlates for local organismal biodiversity in cultivated areas. Results are based on data gathered along a transect from cultivated land through seminatural habitats in Switzerland. Also in Switzerland, Duelli et al. (1999) evaluated the biodiversity of above ground insects, based on the hypothesis, that the diversity of species and genotypes is important for the sustainability of agricultural landscapes.

Risch et al. (1983) reviewed 150 studies dealing with the effects of agroecosystem diversification on the abundance of 198 pest species. It was found that from the examined total of 198 herbivore species 53% were found to be less abundant in the more diversified system, 18% were more abundant, 20% showed variable and 9% no response. He concluded, that a careful diversification of the vegetational component of agricultural habitats often significantly lowers pest populations, this by emphasising the importance to understand the underlying ecological mechanisms of the effects observed. A step towards that direction was done in a selective review of Sheehan (1986) who dealt with the response by specialist and generalist natural enemies to agroecosystem diversification. Smith & McSorley (2000) assumed that the key to the management of pests through polyculture may lie in the specifics of arthropod behaviour and arthropod plant relations. They summarize research results according to theories and underlying mechanisms, as e.g. host finding, interactions within the polycultural systems and emigration from the cropped area.

General properties of crop colonization by herbivores and their predators and parasites were discussed by Price (1976), using soybeans for sampling herbivores and their predators and parasites and the island theory as conceptual basis. The theory explains how distance and area combine to regulate the balance between immigration and extinction in island populations, stating that an equilibrium of species is reached, when the immigration and extinction rates are equal. Price (1976) showed higher colonization and extinction rates at the field edge compared to the centre, but an equilibrium number of species did not develop in time at either site, so data had no predictive value for the development of pest management strategies.

In order to study the complexity and intensity of interactions between plant spatial pattern and herbivore population dynamics, Bach (1980) focused on a single species, the striped cucumber beetle (*Acalymma vittata* Fab.). Population densities of the beetle decreased with increasing plant diversity, but were not affected by plant density. More recently, Hummel et al. (2002) monitored the populations of foliar insect pests and natural enemies in vegetable production systems in USA, incorporating tillage operations and cropping schedules. Most insect populations observed here were significantly influenced by type of insecticide input or ground cover, whereby only few were affected by tillage type.

In the review of Lawton (1983) he tried to alter significantly broad patterns in species richness and plant architecture by focusing on selected trees and their herbivore pests. Stary & Pike (1999) considered the use of beneficial insect diversity in agroecosystem management, but beside the economic benefit of beneficial species also highlight the fact that high biodiversity improves the aesthetics of farmland.

According to Altieri (1999) spatial pattern of landscapes influence the biology of arthropods both directly and indirectly. The importance of spatial scale in the assessment and utilisation of biodiversity effects is shown in Baumgärtner (2000). Duelli et al. (1999) pointed out, that species diversity often depends on the biodiversity of the surrounding landscape, rather than on differing management regimes. An increasing number of studies focus on the exchanges and interactions between agricultural and natural patches. Also according to Dennis & Frey (1992) and Burel & Baudry (1995a,b), interactions and exchanges between ecosystems are an important topic from an ecological point of view and need to be quantified (Stinner et al. 1983).

Biotic interchanges between habitats have been topic of a number of studies in temperate regions, mostly addressing movements of insects on farmlands and between cultivated cropland and hedgerows. Lewis (1969); Bowden (1977); Forman & Baudry (1984) and Maudsley (2002) examined the effect of hedgerows as natural vegetation component in agricultural landscapes on insect populations. Hedgerows enhance overall farmland biodiversity by providing e.g. additional (also overwintering) habitats and thus may contribute to sustainable production. Comparable effect was observed concerning field margins, as examined by Mader (1990); Fry (1991) and Dennis (1992).

Arthropod population movements were studied by Duelli (1990), sampling arthropods between natural and cultivated areas. It was concluded that in cultivated areas a mosaic landscape of small sized crop fields and semi-natural habitats maximizes arthropod diversity and decreases extinction probability. Movements of arthropod communities and tortricid moth (Lep. Tortricidae) between apple orchards and adjacent ecosystems were identified by Altieri & Schmidt (1986) and Jeanneret & Charmillot (1995). Another study concerned the effect of linear barriers like roads on arthropod movements (Mader et al. 1990). Stating the ecological importance of insect emigration Ellingson (1997) reviewed the literature concerning effects of patch geometry and context on insect emigration in patchy habitats. Most important influence factors were patch size, patch context and the insects response to adjacent habitats.

The topic of biodiversity and tropical agriculture in general was discussed by Holloway (1991) and Perfect (1991). Both authors concluded that there is an urgent need for further, detailed research in order to improve agricultural management and to protect endangered species. More specific research was done by Paoletti et al. (1999), evaluating environmental quality in agroecosystems in China, by comparing the abundance of selected insect groups. The importance of a patchy landscape, including woodlots, rationally designed field margins and cropland for creating an ecologically favourable agricultural environment could be shown.

Further, two studies concerning insect pest management in citrus were conducted by James et al. (1998) and Grafton-Cardwell et al. (1999). James observed that the abundance of beneficial and incidental arthropods in ant-free citrus trees is much higher, than in ant-infested trees. Grafton-Cardwell et al. showed that the use of leguminous cover crops in citrus increases the abundance of a predacious mite, controlling two citrus pests in the sample area.

In search for improved control methods of citrus leaf miners and mites by habitat manipulation Van Mele & Lenteren (2002) conducted a survey on current crop management practices in the main production area of two citrus crops in Vietnam. They showed the supporting effect of non crop vegetation on predatory insects.

Concerning the challenge to preserve and restore natural biodiversity, traditional agroforestry systems were studied by several authors. Perfecto et al. (1996) reviewed a number of biodiversity studies carried out in shaded coffee plantations in Latin America and concluded that such habitats provide the last refuges for animals in areas where the original forest cover has disappeared.

Comparisons of the arthropod diversity in multistrata traditional coffee plantations and in natural forests showed similar results, as well as two other studies, dealing with traditional coffee systems in Mexico (Moguel & Toledo 1999) and with cacao plantations (Rice & Greenberg 2000). Klein et al. (2002 a,-b) carried out studies on the influence of different management intensities on arthropods along a transect in cacao and coffee agroforestry systems in Indonesia. No correlation of overall species abundance and diversity with land use intensity was found, but changes in the arthropod community structure along the gradient of increasing management intensity were detected. Further it could be shown that the predator-prey ratio decreased with increasing land use intensity, leading to the hypothesis, that the local farmers of traditional, diverse plantations should have less pest problems due to the higher predator–prey ratio there. Finally they concluded that the transformation of traditional into intensified agroforestry systems had a great impact on arthropod community structure and that changes in species abundance due to land use intensity do indicate changes in the dominant species interactions and thus changes in ecosystem functions.

Concerning biotic interrelations between ecosystems in the tropics, especially those between natural and agricultural ecosystems need to be studied. This in order to understand why species might accept a new habitat in the agricultural landscape, i.e. moving from their former habitat to a new one. Irwin et al. (2000) documented the diversity and movement patterns of insects in a tropical landscape in Costa Rica. By using Malaise traps, leaf beetles (Chrysomelidae) and leafhoppers (Cicadellidae) were caught in forest and adjacent pasture land. It was found that most of the selected species are distributed sparsely in the forest and move preferentially towards the pasture sites. Here the managed habitat even acted as a sink. There was a frequent and pervasive interchange of species between the managed and the unmanaged area.

Beside the study of Irwin et al. (2000) no other research on the interchanges of insects between natural and agricultural areas was carried out in the tropics so far. The question, to which extend specific land use systems in the Tropics might contribute to the preservation of indigenous forest species remains unanswered. So far only few studies focus on the biodiversity of cleared and converted land adjacent to natural areas in the tropics. To further preserve and restore natural biodiversity, landscapes dominated by man need to be included in an overall landscape management strategy. In the process of developing a sustainable landscape management, movement patterns of pests, vectors, pollinators, beneficial organisms and other arthropods, as well as the related plant communities should be considered.

Objectives

This research was conducted in an upland area on the island of Leyte, Philippines, and approached two questions. (1) Which structures and components of the cultural landscape are of significance for conserving arthropod biodiversity, and (2) are there pest- and/or non-pest species which originate from the natural forest and are able to become resident in the man-made systems? In order to answer these questions insect- and plant surveys were conducted and movement patterns of selected insect species examined along a gradient from natural forest through the agricultural land. In particular it was focused on the:

- comparison of the vegetation in natural and agricultural systems;
- comparison of arthropod communities sampled in natural and agricultural systems;
- evaluation of the impact of the vegetational diversity (natural and agriculturally transformed) on arthropod diversity;
- record of movement patterns of selected arthropod species (pest- and non-pest species) between natural and agricultural habitats.

Obtained results are presented and discussed with regard to (1) arthropod diversity and community composition along the transect from the natural through the agricultural systems; (2) abundance of selected species in natural and agricultural systems and finally (3) abundance patterns of selected species within the agricultural land.

2. Leyte overview

2.1 Geography, geology

Leyte is the 8th largest of the Philippine islands and is located in the eastern Visayas between Luzon in the north and Mindanao in the south. The total land area covers 750 000 ha. The island has relatively flat lands around the coastline and mountainous terrain towards the central part, raising up to 1150m, the top of Mt. Pangasugan. The central cordillera ranges from the north to the south of the island and is formed of volcanic as well as of sedimentary and coralline material which was uplifted by geological processes during the tertiary.

The main part of the island is mountainous and can be classified in six slope categories (Table 1). The first two categories of 0-3% and ≥3-8% inclination are suitable for agriculture and urban areas. The slope ranging from ≥8-18% can be used for seasonal and permanent crop production. Slopes of more than 18% are officially excluded from any agricultural- or other use and classified as forest land. But in reality the majority of this land is used by humans. Slopes above 50% are characterized as extremely steep and rough mountain areas which are supposed to be protected forest.

Table 1: Slope classes of Leyte, Philippines (ViSCA, 1996)

Slope class	**Area (ha) Leyte province**	**Share (%)**	**Area (ha) Southern Leyte**	**Share (%)**
0-3%	173,801	30	17,415	10
> 3-8%	46,722	8	9,998	6
> 8-18%	72,207	13	14,093	8
> 18-30%	163,220	29	37,676	22
> 30-50%	84,623	15	41,559	24
> 50- %	30,707	5	52,739	30
Total	571,280	100	173,480	100

2.2 Climate

The climate of Leyte after Köppen (1931) is a tropical rainforest climate, monsoon type. The eastern part of Leyte has a type II climate. It has no distinct wet or dry season but with pronounced rainfall from November to January while the western part, separated by the central cordillera, has a type IV climate with evenly distributed rainfall throughout the year. Total rainfall amounts to more than 3000mm in the upland, in the lowland up to 2600mm. Figure 1 shows the mean daily rainfall of Leyte from 1994 to 2001 (mean of 3 weather stations, one located in the upland, two in the lowland).

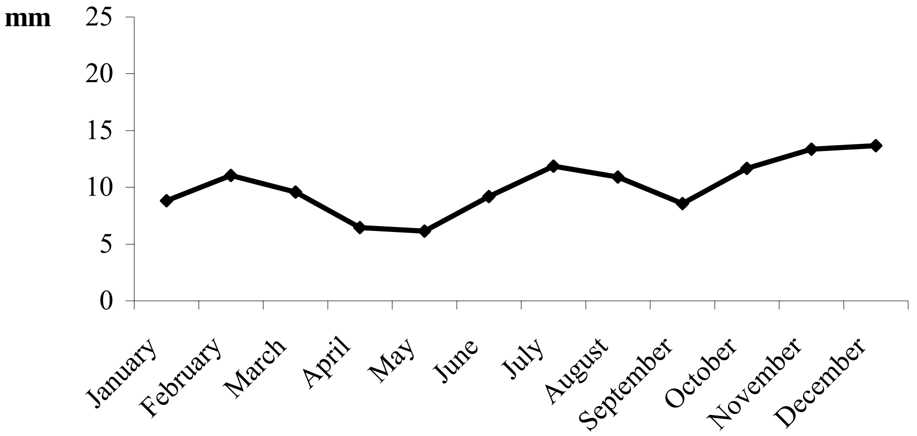

Figure 1: Mean daily rainfall, taken at 3 weather stations (2 lowland, 1 upland) on Leyte, 1994-2001, PNOC (Philippine National Power Corporation) 2002

The temperature at sea level is all year round about 27°C. Day- and night temperatures differ about 5°C. Concerning the upland, temperature shows an average decrease of 0.6°C per every 100m rise in elevation (Müller 1997).

The island regularly faces typhoons with heavy rainfalls and winds of about 69km/h (EDPC 1994, cited in Dargantes 1996), sometimes even up to 150 km/h, causing considerable devastation.

In addition Leyte experiences two types of monsoon (seasonal) winds, affecting the overall climate. The south-west monsoon occurs from June to October and is locally called “Habagat”. Extreme clouds and rainfall are caused at the western side of the island. The northwest monsoon occurs from November to February, locally called “Amihan”. Blowing from the northwest it is causing cloud development and rainfall at the eastern side of the island.

3. Material and methods, site description

3.1 Material and Methods

3.1.1 Site selection

Data were gathered in Lake Danao region on Leyte, Philippines, within the area of the Barangay (village) Cabintan. Research sites were located along the only road, going from Ormoc to Cabintan.

The three sites were selected depending on following criteria:

- Slope position
- Adjacent to the forest at the top of the field
- Shaped by kaingin (slash-and-burn) processes
- Under current cultivation
- No use of pesticides
- Crop composition includes at least 15m² of chayote.

Presence of materials as well as the activities planned for the research at selected sites was discussed and agreed with the farmers in charge.

3.1.2 Soil analysis

In 2001 three soil samples were taken randomly at all sites from each crop patch in about 15 cm depth. The samples were then mixed together. After air drying samples were sieved and weighed. Sieving was done using a 2 mm sieve (for pH and phosphorus (P) determination) and a 0.5 mm sieve for organic matter (OM) and nitrogen (N). All calculations are based on oven dry samples. The chemical analyses were carried out at the Institute of Soil Science, LSU (Leyte State University), Leyte, Philippines.

- Soil pH (pH) value was determined by a potentiometric method. Twenty ml of distilled water were added to a 20 g air-dried soil sample (1:1 ratio). The pH of the solution was then identified with the pH meter.
- Soil organic matter (OM) was determined after the Walkley & Black method (Jackson 1958), also known as wet oxidation method. Organic C is oxidized by potassium dichromate solution in the presence of sulfuric acid. Quantification is performed through titration.
- Total nitrogen (N): Analysis was performed after the Micro-Kjeldahl method (Horwitz 1970). Soil is processed in a digester using sulfuric acid with addition of a salt mixture. The sample is then distilled in order to collect the liberated ammonium nitrogen. Finally, the quantification of nitrogen is done by titration.
- Extractable phosphorus (P) was determined by the Bray method, using the Bray solution (0.1N HCl and 0.03N NH_4F); (Bray & Kurtz 1945). Percent transmittance of the solution was read by a spectronic 20D apparatus.

3.1.3 Vegetation analysis

At each site the flora was recorded within the fields, at the border of the field and within the forest.

On the cultivated land cropping patterns were mapped. The plot size of each crop grown as well as single plants (e.g. pineapples, fruit trees, cassava), planted in-between the crop patches were considered. The agrestal flora within the field was examined from April to June 2001, allowing four observations.

Depending on the homogeneity of the fields, a larger or smaller number of quadrates was placed in order to collect data which are representative of the whole area sampled. As a rule of thumb (CIBA-GEIGY, 1981) six 1 m^2 quadrates per crop grown were selected. A larger number would cover more area but would also increase the influence of heterogeneous properties of the area.

Data collection for each plot was performed in partial compliance with the vegetation analysis method of Braun-Blanquet (1964). With this method a plot is surveyed for plant species and the dominance of single species. This was estimated through a scale for species magnitude composed of seven levels. Plant species were noted down as far as these could be identified in the field, otherwise they were taken to the laboratory for later identification. Instead of the currently planted crop all species of plants were considered, also crop plants that had re-grown on their own. For ease of calculation the range of vegetation cover was calculated as average value, based on Mueller-Dombois & Ellenberg (1974) as shown in table 2.

Table 2: Seven levels of vegetation cover and their description in partial compliance with Braun-Blanquet (Mueller-Dombois, 1974).

Species magnitude	Description	Average vegetation cover %
5	Cover 75 – 100 %	87.5
4	Cover 50 – 75 %	62.5
3	Cover 25 – 50 %	37.5
2	Cover 5 – 25 %	15.0
1	Less than 5 %	2.5
x	Few individuals, evenly spaced	1.0
r	Rare, only one or two individuals	0.1

At the border between the fields and the forest the flora was considered qualitatively as well as this was done in the forest, here concerning the occurrence and distribution of the main trees, ferns, brushes and herbs.

3.1.4 Insect inventory

Diversity as well as the migration of insects were investigated using modified Malaise traps (Malaise 1937, Townes 1962, 1972). The usual Malaise trap is constructed tent-like, made from mosquito net. The lower part is made from black net, which minimizes attraction and avoidance by insects. Instead of side nets it has a separating middle net. The net-roof is inclined and white, simulating the sky for insect eyes. On the highest point there is one collecting container attached to the net. Moving insects, coming from one of the two arrival sides are stopped at the middle wall. Usually insects try to escape by moving upwards, thus once reaching the highest point they fall into the collecting container.

Two of the four traps employed were ordered from ecotech (Bonn), the other two were constructed from locally available net-material and wooden poles, following the design of the factory produced traps. Size was as follows: height: 1.90 m; length: 1.75 m; width: 1.25 m, giving a trapping area of approximately 1.8 m² area.

All traps were modified by the installation of a second collecting container so that the separate retrieval of each of the two arrival sides was made possible (Photo 1). Collecting containers were filled with 70% alcohol.

Photo 1: Adapted Malaise – trap, Cabingtan, 2002

Sampling was done by circulating a set of four traps between the selected sites. Traps were always aligned crosswise to the slope, with the one arrival side facing the forest and the other facing the open field. Within each site the first trap was placed inside the forest with at least 20 m distance to the edge. The second trap was located at the edge, between the forest and the field. Within the cultivated area the third trap was positioned in one of the seasonally planted vegetables and the fourth trap in the perennial chayote (*Sechium edule*). Retrieval always was done after 48 hours. Sampling was carried out twice per month over a total period of 18 months

(Jan-Dec 2001, Apr-Sep 2002), yielding a total of 72 samples for each of the 8 trap arrival sides. In 2001 sampling was conducted at three sites, while in 2002 only two sites could be considered since the owner of the third site started to apply insecticides.

Both collecting containers of each trap from each site were treated separately. From each of the samples, the insect specimens were separated according to orders and divided into species or recognizable taxonomic units (RTU). RTUs represent approximate species, and provide a practical approach to the current, overwhelming problems of taxonomy (Ramsay 1986, Oliver & Beattie 1993, 1996, Hutcheson 1990, Hutcheson & Jones 1999, Hutcheson & Kimberley 1999, Bolger *et al.* 2000). Shannon diversity (Magurran 1988) was calculated and compared concerning the arrival sides, the traps and the three selected sites.

Additional, non permanent methods

During the first catches pan traps were installed inside the malaise traps on both sides along the separating middle net. This is recommended in the literature (Duelli et al. 1999) for including the species which have the habit to let them fall down if they feel in danger. Since no additional catch in terms of species was performed by the pan traps employed, pan traps were not longer installed.

For trapping monophagous insect pests within the damaged crop plots, a Bartak trap from bioform (Nürnberg) was used. This kind of malaise trap only has one pole in the front, holding the collecting container. The back end of the net is spanned down to the bottom, thus the trap and its arrival area is lower, than by malaise traps and especially suitable for trapping the fauna which is concentrated on the vegetation below the trap (http://www.bioform.de/).

Selected species

To determine the interrelations between the agroecosystems and the forest movement patterns of selected species were investigated. Concerning the pest problems of the area the main pest species (24 species) were selected by observation as well as by discussions and field trips together with farmers of Cabingtan.

In addition all the first catches from January to April 2001 were screened and compared with each other again for the selection of species, which, based on their abundances, seem to originate in the forest but are able to visit or even immigrate into the agricultural system (10).

The abundance of the 34 selected species for each catch and collecting container always was recorded separately. Based on the abundance of these 34 species in the different collecting containers at all the three sites the movement patterns were determined and compared between the sites.

Identification for the selected 34 species was done up to species level by specialists at the Department of Entomology, University Los Banos, Philippines (UPLB). The reference collection partly is stored at the Museum of Natural History at the Leyte State University as well as at UPLB.

Occurrence and behaviour of the selected species was observed in the field, restricted from light- and weather conditions. During observation natural enemies of the selected pest species, which were not abundant enough in the catches for the determination of their movement pattern were concerned as well.

3.2 Description of Leyte upland

Research sites were located within the region around Lake Danao, which is part of the Leyte National Park and watershed area for the two main cities of the island, Tacloban and Ormoc (Fig. 2). The topography of the area is moderately to steep sloping with an annual precipitation higher than 3500mm.

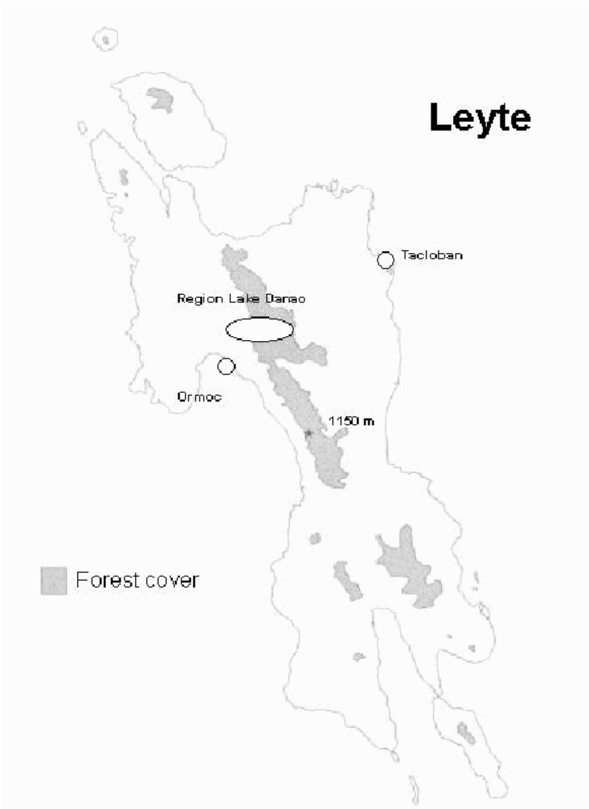

Fig. 2: Leyte island with its remaining forest, Lake Danao National Park and the two main cities

3.2.1 Socio-economic situation

When the Lake Danao National Park (also named Imelda Marcos Park) was established in 1972 the few residents and their agricultural land were legalized. Any further settlement or extension of land clearing processes was prohibited. Officially national parks are declared as protected area and settlements as well as land use are illegal. Since opportunities to achieve revenue are limited and arable land is barely sufficient in the lowland people are forced to move up the hills, clearing land by slash-and-burn (kaingin) to earn their living. The procedure is illegal and settlers don’t have any proprietary right depending on the land, which is sometimes already occupied by their families since 1972. There are no data available about the actual amount of land area, used for agriculture because there is no control of the land use in the area which are officially classified as forest land or protected zone. The majority of Leyte farmers have land holdings of less than one hectare up to 5 hectare (GROETSCHEL et al. 2001). The surplus harvest is sold in the lowland, where higher temperatures hardly allow vegetable production. Since the demand is high, farmers try to produce as much as they can. The input in agricultural activities is low because of the poor financial resources of the farmers, their low education level and because of the unclear property rights. If the used land no longer returns enough profit, new land is opened by migrating up hill, where the last primary forest is located.

3.2.2 Description of the landscape

Due to described slash-and-burn activities the landscape was and is shaped in a characteristically way. The presently cultivated patches are haphazardly distributed between settlement areas, fallow or degraded land and pastures.

Photo 2: Research site at Leyte Upland, 2002

On the upper edge of the slopes, at the steepest parts, too steep for agricultural use, fragments of natural forest are left. Towards the remote inner part of the mountain range, more forest is left, building connected patches which finally pass over to a continuous and still primary forest cover.

Within the forest the climate is more humid and temperature is about 1-2 degree lower than in the open land. Due to its high humidity the forest can be classified as mossy forest, although this usually is located at an elevation ≥1000m a.s.l. Trees are jolted, cambered and crowns and stems are trimmed with epiphytes. The undergrowth is very dense, containing diverse climbing plants, hygrophilous ferns and palms. Conspicuous are the numerous tree ferns (*Cyathea* sp.) in all sizes. The upper canopy was estimated to reach a maximum height of 30m with an average of 20m. Stems are dominated by diameters of < 40 cm in breast height (DBH), canopy forming trees can have up to 1.5 m (DBH). Following table (3) shows the list of the qualitatively documented plant species within the forest.

Table 3: Upland forest vegetation at Cabintan, Leyte, identified as close as possible, 2002

Climbing plants	**Family**
Rattan spp.	Arecaceae
Dioscorea sp.	Dioscoreaceae, section Enantiophyllum
Lindsaea sp.	Lindsaeaceae (Fern)
Freycinetia spp.	Pandanaceae
cf. Dinochloa sp.	Poaceae
Uncaria spp.	Rubiaceae
Stem climbing	
Raphidophora sp.	Araceae
Piper spp.	Piperaceae
Selaginella sp.	Selaginellaceae
Epiphytes	
Asplenium nidus	Aspleniaceae (Fern)
? spp.	Orchidaceae
Lygodium sp.	Schizaeaceae (Fern)
Pteridophyta	various
Undergrowth	
Alocasia zebrina	Araceae
Canarium cf. asperum	Burseraceae
Chloranthus erectus	Chloranthaceae
Calophyllum sp.	Clusiaceae
juvenile tree ferns	cf. Cyatheaceae
Davallia sp.	Davalliaceae

Trichomanes cf. javanicum Bl.	Hymenophyllaceae
Trichomanes sp.	Hymenophyllaceae
Cinnamomum cf. mercadoi	Lauraceae
cf. Actinodaphne	Lauraceae
Tapeinidium sp.	Lindsaeaceae
Tapeinidium pinnatum (Cav.) C.Chr.	Lindsaeaceae
Phrynium sp.	Marantaceae
Angiopteris erecta	Marattiaceae
cf. Memecylon spp.	Melastomataceae
Astronia sp.	Melastomataceae
Ficus cf. nota	Moraceae
Ardisia sp.	Myrsinaceae
Syzygium spp.	Myrtaceae
Neonauclea sp.	Rubiaceae
Palaquium sp.	Sapotaceae
Selaginella spp.	Selaginellaceae
Elatostema sp.	Urticaceae
Tree species	
Buchanania arborescens	Anacardiaceae
Dillenia philippinensis Rolfe	Dilleniaceae
cacinaceae cf, Gomphandra sp./ cf. Platea excelsa	
Lasianthus sp.	Rubiaceae

Towards the edge of the forest the vegetation becomes less dense, middle sized trees often are cut down and the groundcover is dominated by grasses. At the margin of the forest the first open land pioneer plants can be noticed e.g. *Macaranga cf. philippinensis* (Euphorbiaceae) and *Melastoma sp*. (Melastomataceae).

On the cleared land the vegetation consists of grasses and herbs beside the crop plants. The most dominant species are given in table 4.

Table 4: Dominant species of grasses and herbs within cleared land, Leyte upland 2001

Family	Genus and species
Araceae	*Colocasia* sp.
Asteraceae	*Ageratum conyzoides* L.
Asteraceae	*Bidens pilosa* L.
Asteraceae	*Crassocephalum crepidioides* (Benth.) S. Moore
Asteraceae	*Mikania cordata* (Burm.f.) B.L.Rob.
Asteraceae	*Erechtites valerianifolia* (Wolf) DC.
Caryophyllaceae	*Drymaria cordata* (L.) Willd.ex Roem. & Schult.
Ferns	6 species
Poaceae	*Axonopus compressus* (Sw.) Beauv.
Poaceae	*Eleusine indica* (L.) Gaertn.
Rubiaceae	*Borreria* sp.
Verbenaceae	*Stachytarpheta jamaicensis* (L.) Vahl

Farmers are cultivating vegetables on small scale level. Common is the cultivation of 2-3 vegetable crops within one year at the same plot, whereby there is no planned crop rotation. Apart from vegetables two perennial crops are grown (*Sechium edule*; *Musa textiles*). All agricultural crops grown in the region are given in table 5.

Table 5: Crops grown in the upland of Leyte, Philippines, 2002

Seasonal, grown in patches	
Spring onion	*Allium fistulosum* L.
Cabbage	*Brassica oleracea* L.
Chinese cabbage	*Brassica rapa* L.
Pechay	*Brassica rapa ssp. chinensis* L.
Sweet pepper	*Capsicum annuum* L.
Taro	*Colocasia esculenta* L. Schott
Cucumber	*Cucumis sativus* L.
Squash	*Cucurbita* sp.
Carrots	*Daucus carota* var. *sativus*
Sweet potato	*Ipomoea batata* L.
Tomato	*Lycopersicon esculentum* Mill.
Cassava	*Manihot esculenta* Crantz.
Beans	*Phaseolus lunatus* L.
Eggplant	*Solanum melongena* L
Tannia	*Xanthosoma sagittifolium* L. Schott
Corn	*Zea mais* L.
Perennial, grown in patches	
Abacca	*Musa textiles* Nee.
Chayote	*Sechium edule* (Jacq.) Sw.
Fruits, grown in-between patches	
Pinapple	*Ananas comosus* L. Merr.
Jackfruit	*Arthocarpus heterophyllus* Lam.
Papaya	*Carica papaya* L.
Citrus	*Citrus* spp.
Banana	*Musa x paradisiaca* L.

Under given conditions vegetable crops need less than three months from planting to harvest. There is just one perennial vegetable grown, chayote, being harvested all year round and only replanted once productivity decreases remarkably after 2-6 years.

4. Arthropod diversity and community composition along a transect from natural through cultural habitats in the upland of Leyte, Philippines

Abstract

In many regions of tropical SE Asia, cultivated and degraded land outnumbers by far natural ecosystems. To further preserve and restore natural biodiversity, landscapes dominated by man need to be included in research activities with view of the development of an overall landscape management strategy. The objectives of this study, dealing with the effects of habitat destruction on the arthropod community of a Philippine upland, were to compare the arthropod communities of different habitats between the natural and agricultural ecosystems with increasing distance to the forest, in relation to the vegetation. Insect sampling was carried out using Malaise traps, whereby four habitats were considered: (1) forest interior, (2) forest margin, (3) vegetable fields and (4) chayote (the only perennial vegetable of the area) fields. Arthropod diversity, composition of the arthropod community and trophic guild composition at habitats were defined and discussed. It was found that plant diversity, vegetation structure and taxonomic composition as well as differences in the turnover of the vegetation at habitats (productivity of vegetation) influence arthropod groups or species in the study area.

4.1 Introduction

Tropical humid forests, which comprise a major part of the terrestrial biodiversity (Myers *et al.* 2000), are dwindling at an alarming rate (Tole 1998, Dudley *et al.* 1998, Laurance *et al.* 2000, Chazdon 2003). The tropical forests of SE Asia are among the most seriously affected due to commercial logging activities along with slash-and-burn agriculture (Laurence 1999, Fu 2003, Giri *et al.* 2003). Especially endangered are biodiversity hotspots such as the Philippine archipelago, which comprise scores of endemic species (Brooks *et al.* 2002). To further preserve and restore natural biodiversity, landscapes dominated by man need to be included in research activities with view of the development of an overall landscape management strategy.

Numerous studies deal with the consequences of forest disturbance and fragmentation for fauna and flora, including aspects of diversity, ecosystem services and species interrelations (Watt *et al.* 1997, Didham *et al.* 1998, Bawa & Seidler 1998, Tabarelli *et al.* 1999, Laurance *et al.* 2000, Willott *et al.* 2000, Vasconcelos *et al.* 2000, Davis 2000, Hamer & Hill 2000, Brook *et al.* 2003). But quantifying the extent of diversity losses as a consequence of these human activities remains a challenge for those taxa with the highest species diversity, such as insects in tropical forests (Erwin 1982; Hammond 1994). For most tropical insect communities, even an assessment of local diversity under different ecological situations has not yet been achieved (Beck *et al.* 2002). The few studies that are dealing with alterations of tropical insect communities in relation to agricultural activities exclusively focus on selected insect groups, such as geometrid moth (Intachat *et al.* 1997, Intachat *et al.* 1999), Noctuidae (Schulze 2000) or Lepidoptera (Holloway 1998). Even less is known about changes of insect communities along habitat gradients, including natural forest, forest margins and different agricultural habitats. An exception is the study of Beck *et al.* (2002) on Geometridae on Borneo, along a transect ranging from primary forest to cultivated land, who found significantly lower diversity in agricultural areas as compared to the forest.

Tscharntke *et al.* (2002) stated that species are differentially affected by habitat fragmentation. As a consequence, community structure, interspecific interactions, and ecological functions may change. Therefore, it is necessary to consider a broad spectrum of the existing taxa. In order to define the effects of habitat destruction on the arthropod community of a Philippine upland area the objectives of the present study were: To compare the total arthropod inventory and trophic guild composition, between the natural and agricultural ecosystems with increasing distance to the forest, in relation to the vegetation.

4.2 Materials and Methods

The study was conducted in 2001 (January-December) in a slopy watershed area, located at about 800 m a.s.l in the lake Danao region of Leyte island, Philippines (11°05'18''N; 24°42'35''E). The climate is typical of a tropical upland area, with a maximum temperature range from 20 to 28 °C and an annual precipitation of about 3500 mm. In 2001, annual precipitation was only 2778 mm due to El Niño. There are two seasons of mainly dry periods (February to June, and September to October), and two seasons of more or less continuous rainfall (July to August, and November to January). Despite the relatively low altitude, the original vegetation is represented by a mossy forest. The average canopy height is about 20 m, with a maximum height of 30 m. Most stems have diameters up to 40 cm in breast height (dbm), but canopy building trees reach up to 1.5 m dbm. Tree species diversity is high, at least 100 species were recorded at the research locality. The undergrowth vegetation is very dense, with a variety of climbing plants, ferns, tree ferns and palms (Table A1).

Due to slash-and-burn activities within the last ten years, formerly forested areas were transformed into cultivated land, consisting of arable fields, sporadic fruit trees, bushes, fallow land and degraded areas. Forested areas are replaced by agricultural land which expands towards the upper slope. At the border between forest and cultivated land, the edge of the forest is composed of sparse stands of pioneer tree species such as *Macaranga cf. philippinensis*

(Euphorbiaceae) and *Melastoma sp*. (Melastomataceae). The ground cover is dominated by grasses. The arable fields are dominated by seasonally changing vegetables, which are grown in small plots of about 5 – 50 m² size. The main crops grown were tomato (*Lycopersicon esculentum* Mill.), spring onion (*Allium fistulosum* L.), lima bean (*Phaseolus lunatus* L.), eggplant (*Solanum melongena* L.) and pechay (*Brassica rapa ssp. chinensis* L) The only perennial vegetable was chayote (*Sechium edule* (Jacq). Sw.). No pesticides and herbicides were applied at the field sites studied.

The study was carried out at three localities of the same slope, at about 1500 m distance from each other. Each locality included four types of habitat, where insect sampling was conducted: (1) the forest interior (at the upper slope) at a distance of about 25 m from the edge of the forest, (2) the forest margin, (3) the vegetable fields at distances between 10 - 27 m from the edge of the forest and (4) the chayote fields at distances of about 50 m from the edge of the forest.

Insect sampling was carried out using Malaise traps (Malaise 1937, Townes 1962, 1972). All four traps per locality were aligned parallel to each other, along the contour line. Traps were modified by installing a second collecting jar, allowing separate collection of individuals approaching the two arrival sides. Hence, each of the traps yielded two samples from two opposite directions at the same time the one collecting individuals moving from the forest towards the field, the other one collecting individuals moving from the open land towards the forest. Collecting jars were filled with 70% alcohol and kept open for 48 hrs, then cleared from the collected individuals. Sampling was carried out rotationally at the three localities over a period of 12 months. Sampling frequency was about three weeks at each of the three localities from January to December 2001, which resulted in a total of 16 samples per locality. Thus for each of the eight trap arrival sides of the three localities taken together, a total of 48 samples were collected. During the first catches pan traps were installed inside the malaise traps on both sides along the separating middle net for including the species which have the habit to let them fall down if they feel in danger. Since no additional catch in terms of species was performed by the pan traps employed, pan traps were not longer installed.

For each of the samples, insect specimens were separated by orders, assigned to recognizable taxonomic units (RTU) and counted per RTU. RTUs represent approximate species, and provide a practical approach to the current, overwhelming problems of taxonomy (Ramsay 1986, Oliver & Beatie 1993, 1996, Hutcheson 1990, Hutcheson & Jones 1999, Hutcheson & Kimberley 1999, Bolger *et al.* 2000).

All RTUs were present during all periods of the study, at all the three sites considered, i.e. no differences between sites and no relationships between occurrence and seasonal weather conditions were observed, referring to the inventory. Therefore, species abundances recorded at the three localities over the total sample period were pooled with respect to habitats and arrival sides (N=48).

For further data processing the most numerous arthropod orders (Arachnida, Coleoptera, Diptera, Hemiptera, Hymenoptera, Lepidoptera) were considered since single individuals of other orders (Blattodea, Collembola, Dermaptera, Ephemeroptera, Isoptera, Mantodea, Neuroptera, Odonata, Orthoptera, Thysanoptera) were only erratically caught.

In order to define the distribution of arthropod groups at the four habitats which are similar in their nutritional requirements and feeding habits, the classification of trophic guilds according to Stork (1987) and Moran & Southwood (1982) was employed. They distinguished following trophic guilds: parasitic on insects (pa); blood sucking (bs); pollinator (po); fungivorous, saprophagous, xylophagous (sx); phytophagous (ph) and predator (pr). For the definition of trophic guilds, four samples from each location were considered (N= 12). Here, individuals were taxonomically identified as far as possible and necessary to define their feeding habits. If classification of individuals was not possible, determination of feeding habits was based on structure and mechanism of the mouthparts.

For each sample, Shannon diversity was calculated (Magurran 1988). From these, mean values with standard errors were calculated per trap arrival side, pooling all three localities (N=48). Differences between the four habitats were tested using ANOVA, based upon all Shannon diversity values obtained at the three locations, pooled per habitat (N=96).

The two corresponding arrival sides of the traps per habitat were tested for significant differences in diversity values of the tree locations using Kolmogorov-Smirnov test. This test is non-parametric (distribution independent) for equality of distribution, and indicates the probability that two samples have been taken from the same parent population.

Data were encoded and processed using Excel 4.0 (Microsoft Windows XP 2002) and statistical analyses were performed using the software programme PAST (Hammer *et al.* 2001).

4.3 Results

The most frequently occurring arthropod orders, recorded from malaise traps in 2001, were Arachnida, Coleoptera, Diptera, Hemiptera, Hymenoptera, Lepidoptera. A total of 67,035 individuals were trapped. Arthropod diversity was found to be significantly different between all habitats investigated (Tab 1). Composition of arthropod communities at the forest and the habitat at the edge of the forest (margin) differ significantly from the one at chayote ($p \leq 0.001$). Composition of the arthropod community at the margin is significant different from the one at the vegetable ($p \leq 0.001$). The other comparisons are different at $p \leq 0.05$.

Tab. 1: Differences of Shannon diversity between habitats (ANOVA), (N=96), ($p \leq 0.05$*; $p \leq 0.001$**)

Forest – Margin	*
Forest – Chayote	**
Forest – Vegetable	*
Margin – Chayote	**
Margin – Vegetable	**
Chayote – Vegetable	*

Differences of arthropod diversity between the opposite arrival sides of the traps within each habitat are shown in table 2. In terms of diversity, only the opposite arrival sides of the trap in the vegetable are not significantly different from each other.

Tab. 2: Differences of Shannon diversity between corresponding arrival sides of traps at four habitats (Kolmogorov-Smirnov), (N=48), ($p \leq 0.05$*; $p \leq 0.001$**)

	Shannon diversity
Forest	**
Margin	*
Vegetable	n.s.
Chayote	*

Shannon diversity values calculated for the arthropod RTUs were always higher in the forest-facing arrival sides of the traps (Fig 1). Arthropod diversity was highest at the forest margin, followed by the forest interior. Diversity decreased towards the vegetable and chayote, with increasing distance into the agricultural area.

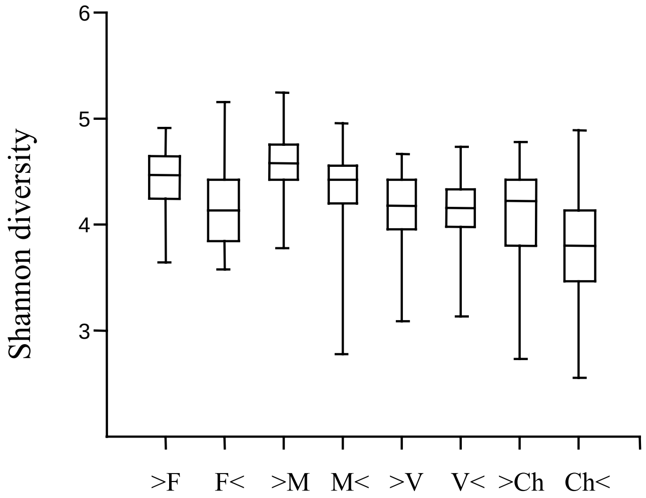

Fig. 1: Shannon diversity of arthropod RTUs for the two arrival sides of each trap; Leyte 2001 (N=48/arrival side, median given in box; whiskers indicate min and max values)

(->F, forest facing side of trap in the forest; F<-, field facing side of trap in the forest;
->M, forest facing side of trap at the margin; M<-, field facing side of trap at the margin;
->V, forest facing side of trap in vegetables; V<-, field facing side of trap in vegetables)
->Ch, forest facing side of trap in Chayote; Ch<-, field facing side of trap in Chayote;

Mean numbers of RTUs and individuals counted per arrival side are given in Fig. 2. Highest values were observed at the forest margin, decreasing towards the open, cultivated land.

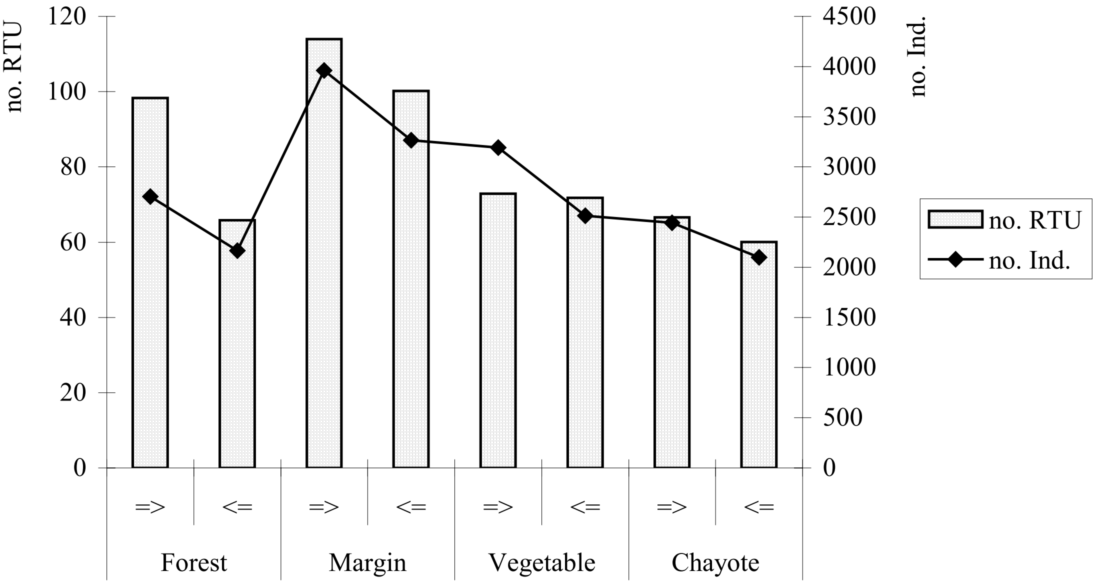

Fig. 2: Mean number of arthropod individuals and RTUs at four habitats (N=48) 2001

The mean number of RTUs of the six main orders in the respective catches are presented in Figure 3. Diptera and Lepidoptera were the most common. The number of RTUs among the Hymenoptera is highest in the forest and decreases with increasing distance from the forest. Most of the Coleoptera RTUs were found at the edge of the forest, followed by the cultivated land.

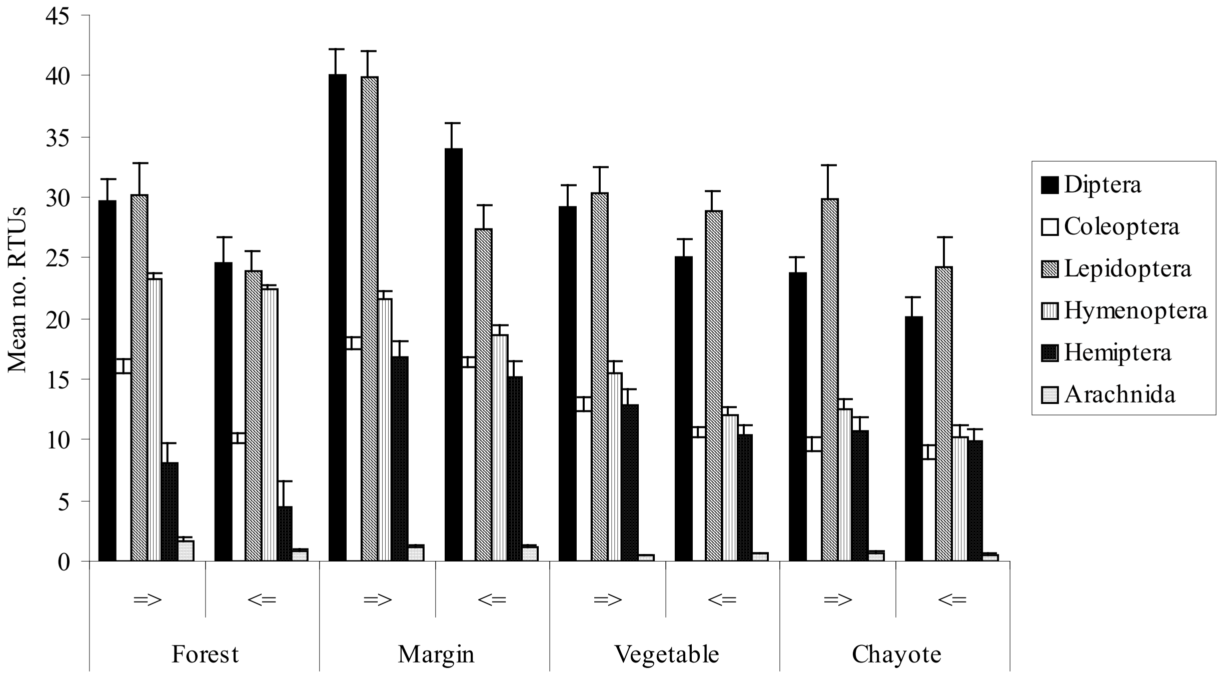

Fig. 3: Association between habitat, movement direction and the mean (+SE) number of RTUs within the five most common arthropod orders per sample (N=48+SE); 2001.

Compositions of the trophic guilds within the investigated, undisturbed and disturbed ecosystems are shown in Figure 4. The proportion of phytophagous insects was highest in the disturbed habitats, while in the forest, the proportion of predators and parasitoids was highest. Most pollinators were recorded in the cultivated land.

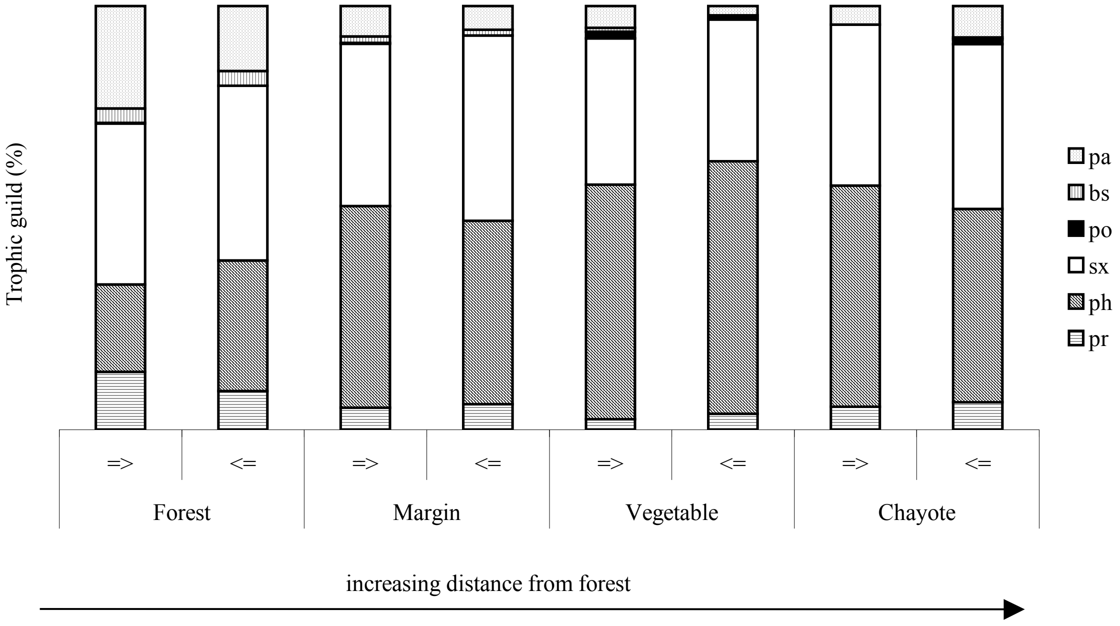

Fig. 4: Percentage share of individuals affiliated to trophic guilds (mean of two sites with four catches from each site (N= 8)
(pa = parasitic on insects; bs = blood sucking; po = pollinator; sx = fungivorous, saprophagous, xylophagous; ph = phytophagous; pr = predator)

Differences in abundance of the 20 most noxious pest species of cultivated crops at the four habitats are given in Figure 5. (Criteria of selection were based on field observations and additional information according to the assessments of and together with farmers; list of selected pest species in annex, Table A 4).

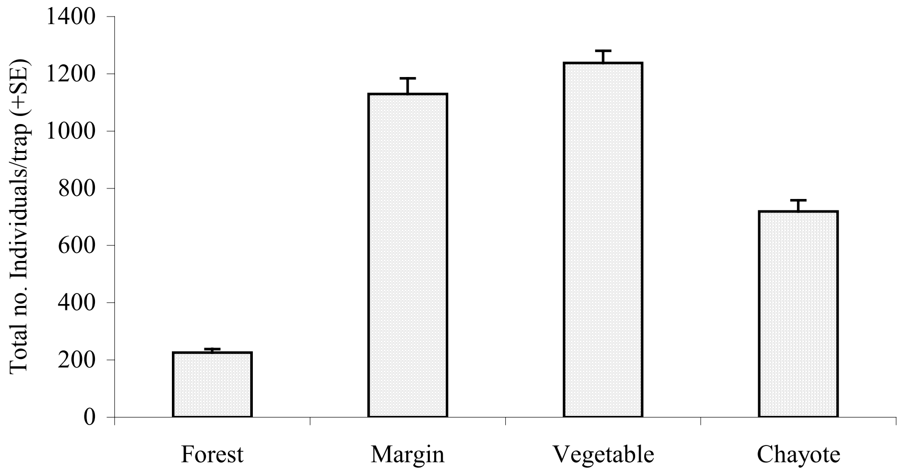

Fig. 5: Total abundance of the 20 most noxious pest species (N= 48+SE), Leyte 2001

Concerning the flora, classification of the climbing and stem climbing plants, epiphytes, the undergrowth vegetation and the tree species of the plots in the forest, as far as possible to determine, is given in Table A 1 (annex). Plant communities of the forest and the agricultural area do not overlap (for the vegetation of the agricultural area see materials and methods and Table A2, A3, annex).

4.4 Discussion

Malaise traps

Malaise traps as used in this study mainly trap ground moving, low flying (up to trap height), and emerging arthropods, thus focus on chiefly mobile arthropod species (Townes 1962, 1972; Hutcheson & Kimberley 1999, Hutcheson & Jones 1999, Butler et al. 1999). So, although numerous flightless RTUs were trapped, the sampling method most probably underestimated the abundance of the arthropod fauna (e.g. arthropods predominantly living in the canopy or in the soil). In order to attain representative samples, yellow pan traps were placed along the separating middle net of the malaise traps during the first four samplings. This is recommended in the literature (Duelli et al. 1999) for including the species which have the habit to let them fall down when they feel in danger and less mobile species. But since no additional RTUs and/or numerous individuals of specific RTUs were trapped, yellow pan traps were not longer used. Due to restricted man-power and laboratory facilities available no further methods (e.g. pitfall traps, canopy fogging, photo eklektor) were tested or employed. However, in comparison to other, single used trap types or methods, malaise traps provide a remarkably broad range of RTUs, thus are appropriate for basic arthropod surveys.

Differences between arrival sides

Significant differences were found between the composition of insect communities approaching the corresponding arrival sides of the traps in the forest, at the edge of the forest and in chayote. Differences between insect communities at the edge of the forest are due to margin effects and will be discussed later. Concerning the vegetable habitat the similar arthropod communities were dominated by agricultural pests, which concentrate on their food source, the vegetable crops. The perennial chayote is not visited by specific arthropod pests and provides shelter for various RTUs. Differences between corresponding arrival sides might reflect the intention of RTUs to move towards the forest, their native habitat, or towards the open, the agricultural land. There is no explication from the literature for the highly significant differences in the forest interior. Since no other influence could be identified, we assume, that even inside the forest the movement direction towards the deeper forest or towards the agricultural land has an influence on arthropods in this habitat.

Diversity and numbers of RTUs along the forest – field gradient

In the present study the main reason for the decrease of the total arthropod diversity towards the field was assumed to be the loss of micro habitats towards the agricultural land. In the forest the vegetation is composed of trees, bushes, ferns, epiphytes and undergrowth vegetation which in total provides a manifold structure of plant organs from the bottom up to the canopy, thus a high number of micro habitats. In the agricultural land a smaller number of habitats is composed by similar crop plants and weeds. Similarly, but only regarding Lepidoptera, Schulze et al. (2004) reported a decrease in diversity from the forest towards the field, when sampling the abundance of Lepidoptera species richness from old-grown forest towards maize fields on Sulawesi. With regard to geometrid moth, Beck (2002) found a significant lower diversity of species in cultivated land, compared to primary forest in Borneo. He also related the loss of geometrid species in the modified habitats of the agricultural land to a loss of (micro-) habitats.

Only concerning the mean number of Lepidoptera RTUs along the habitat gradient, our results show merely small differences between forest and agricultural land. The RTUs from the forest were not the same as the RTUs from agricultural habitats. Intachat et al. (1999) examined geometrid moth populations in logged and unlogged forests of peninsular Malaysia and found only little reduction in the number of species in the logged forests, and similar to the present study, a shift in moth species composition. Concerning the present results, the similar numbers of Lepidoptera RTUs in the forest and the agricultural land can be explained with a change of the RTUs involved. The loss of forest Lepidoptera RTUs, due to habitat loss is compensated by an increase of other RTUs which follow the crop plants as e.g. the pink eggplant borer, *Leucinodes orbonalis* (Guenee). However, regarding all arthropod RTUs, the loss of arthropod species from the forest towards the field cannot be compensated by the immigration of new species, as shown by the decrease of the total diversity along this gradient.

Diversity and numbers of RTUs at the forest edge

Arthropod diversity, number of individuals and RTUs were highest in samples taken at the forest margin. Major et al. (2003) and Majer et al. (1999) found that interior sites (inner forest) tended to have fewer species and individuals than edge habitats, when examining arboreal insects in south-eastern Australia. Bedford & Usher (1994) achieved similar results for the temperate climate, when they investigated the distribution of arthropod species (Carabidae and Araneae) across the margins of farm woodlands in Scotland. Reasons for the higher diversity of margin habitats might be their characteristics: Arthropods move from one habitat to another in their search for food, shelter and suitable breeding sites. Consequently, individuals of all adjacent habitats can be caught at the margin.

The forest margin in the present study is characterised by its own vegetation (pioneer species and grasses) which extends about 5-15 m in width. The influence from abiotic (changes in the environmental conditions, temperature, microclimate, (further described by Matlack 1993), direct (changes in the abundance and distribution of species) and indirect (changes in species interactions) biological edge effects as classified by Murcia (1995) may be responsible for this situation. Due to these effects, various microhabitats might be developed and used by specialised species. For example, Bedford & Usher (1994) found two Carabidae and one Araneae species which appeared to favour the edge zone over both, the field and the forest interior and seemed to be specialised on this margin habitat. In conclusion, the high diversity in the forest margin is due to its position as a transitional zone, where individuals of adjacent habitats as well as specialized species are present.

Range of diversity values and numbers of RTUs

Differences in arthropod diversity between habitats are significant, but nevertheless small. Also Hutcheson & Kimberley (1999) did not find large differences between beetle species richness of a forest and a shrubland habitat on New Zealand. They concluded that although general habitat types (or successional stages) have characteristic insect communities, plant species composition does not appear to have a high influence on total diversity. They assumed that high species richness and abundance in shrubland compared to the forest habitat are due to the higher turnover of vegetation occurring within successional stage. The vegetation of the agricultural land in the present study has a high turnover as well. Here a part of the produced biomass is taken out by weeding and with harvest products, followed by the consecutive regrowth of weeds and crops, whereby each stage might support different arthropod groups or species. In the forest the high diversity is related to the high number of habitats (see above).

Blanche (2000) examined the diversity of insect-induced galls along a temperature-rainfall gradient in the tropical savannah region of Australia and concluded that it is rather the taxonomic composition of the vegetation than the number of plant species included, which has the greater influence on gall-inducing insect species richness. However, it should be considered that plant species varied greatly in susceptibility to galling. In contrast, Novotny et al. (2004) found that most of the herbivore diversity was associated with plant diversity (on family or genus levels) when they determined the local species richness of leaf-chewing insects feeding on woody plants in a Papua-New-Guinea rainforest. Taken together, plant diversity, taxonomic composition, as well as differences in the turnover rate of the vegetation at habitats, are involved in determining the abundance of arthropod groups or species and therefore might account for the small differences in arthropod diversity between habitats in the present study.

Trophic guilds

Hutcheson & Kimberley (1999) in their research used malaise traps and sampled more predacious and less herbivorous beetles in podocarp, broadleaf forest sites compared to heathland and shrubland sites. They explained differences in the distribution of trophic guilds with the influence of habitat processes (e.g. changes in plant physiology due to environmental stress) on abundance and composition of dominant arthropod species within local communities. The appearance of more predacious and less herbivorous arthropods in the forest compared to open land is similar to the results presented here.

Oksanen et al. (1981), Oksanen (1990a, b) and Fretwell (1977, 1987) tried to explain the distribution of trophic guilds between habitats by formulating a theory (OF-theory). The theory says, that in natural stands of productive vegetation food webs develop in which activity of herbivores is consonantly restricted by resident or visiting populations of carnivores or parasites. The theory asserts that in ecosystems with very low productivity, there is not enough food to sustain a second or third trophic level. Applied to the presented results, the forest can be regarded as “natural stand of vegetation” with high productivity. There, a higher percentage of parasitoids and predators restricts the phytophagous insects to a lower percentage than in arable fields, which have a comparably low productivity compared to the forest habitat. The consecutively disturbed vegetable and chayote plots correspondingly had a higher percentage of phytophagous insects.

Beside productivity of vegetation, vegetation structure might further explain the distribution of trophic levels between habitats. Russel (1989) found that the control of populations by natural enemies can be stronger in structurally diverse vegetations. This would be conform with the OF-theory if we assume that more diverse structure also means high plant diversity which could offer more food, shelter and breeding sites. This would be applicable to the present results, where structural diversity and ratio of parasitoids and predators to phytophagous individuals declines from the forest towards the field (margin excluded). Taken together, habitat processes, aspects of the OF-theory as well as the dissimilar vegetation structure seem to account for the distribution of trophic guilds at the research area.

Regarding abundances of selected pest species, most individuals were found at the vegetable habitat, followed by the margin. One reason might be that the margin acts as a physical barrier to most pest insects which move in the search for resources from the field habitats. Only few individuals penetrate into the forest. Even single individuals of the selected pest species were caught and/or observed in the forest, none could be noticed feeding in the forest (observations were made after retrievals of traps and on ten additional days; total duration about 150-200h). Thus it is assumed, that the pest insects which were found in the forest can not survive here and arrived accidentally. It should be mentioned, that most noxious pest species are specialized on agricultural crops and probably were introduced with their non-native host plants (e.g. eggplant, tomato, beans).

Insect populations respond to the availability of appropriate resources (e.g. Hoskin & Hutcheson 1986, Hutcheson 1991, White 1993, Stamps & Linit 1998), which, in the research area, are mainly affected by slash-and-burn agriculture. In the present study it was tried to define the main impact factors in the original and the modified habitats on the insect community. It was found that plant diversity, vegetation structure and taxonomic composition as well as differences in the turnover and productivity of the vegetation at habitats influence arthropod groups or species in the research area. In order to define the effects of habitat destruction on the arthropod community of a Philippine upland area the present results provide basic data which should be extended by further studies on selected arthropod groups or species.

Annex:

Table A1: Upland forest vegetation at Cabintan, Leyte, as far as identified, 2002

Climbing plants	Family
Rattan spp.	Arecaceae
Dioscorea sp.	Dioscoreaceae, section Enantiophyllum
Lindsaea sp.	Lindsaeaceae (Fern)
Freycinetia spp.	Pandanaceae
cf. Dinochloa sp.	Poaceae
Uncaria spp.	Rubiaceae
Stem climbing	
Raphidophora sp.	Araceae
Piper spp.	Piperaceae
Selaginella sp.	Selaginellaceae
Epiphytes	
Asplenium nidus	Aspleniaceae (Fern)
? spp.	Orchidaceae
Lygodium sp.	Schizaeaceae (Fern)
Pteridophyta	Various other ferns
Undergrowth	
Alocasia zebrina	Araceae
Canarium cf. asperum	Burseraceae
Chloranthus erectus	Chloranthaceae
Calophyllum sp.	Clusiaceae
juvenile tree ferns	cf. Cyathea
Davallia sp.	Davalliaceae
Trichomanes cf. javanicum Bl.	Hymenophyllaceae
Trichomanes sp.	Hymenophyllaceae
Cinnamomum cf. mercadoi	Lauraceae
cf. Actinodaphne	Lauraceae
Tapeinidium sp.	Lindsaeaceae
Tapeinidium pinnatum (Cav.) C.Chr.	Lindsaeaceae
Phrynium sp.	Marantaceae
Angiopteris evecta	Marattiaceae
cf. Memecylon spp.	Melastomataceae
Astronia sp.	Melastomataceae
Ficus cf. nota	Moraceae
Ardisia sp.	Myrsinaceae
Syzygium spp.	Myrtaceae
Neonauclea sp.	Rubiaceae
Palaquium sp.	Sapotaceae
Selaginella spp.	Selaginellaceae
Elatostema sp.	Urticaceae
Tree species	
Buchanania arborescens	Anacardiaceae
Dillenia philippinensis Rolfe	Dilleniaceae
Gomphandra sp./ cf. Platea excelsa	Icacinaceae cf.
Lasianthus sp.	Rubiaceae

Table A2: Most dominant species of wild grasses and herbs within cleared land, 2001

Family	**Genus / species**
Araceae	*Colocasia* sp.
Asteraceae	*Ageratum conyzoides* L.
Asteraceae	*Bidens pilosa* L.
Asteraceae	*Crassocephalum crepidioides* (Benth.) S. Moore
Asteraceae	*Mikania cordata* (Burm.f.) B.L.Rob.
Asteraceae	*Erechtites valerianifolia* (Wolf) DC.
Caryophyllaceae	*Drymaria cordata* (L.) Willd.ex Roem. & Schult.
Ferns	6 species
Poaceae	*Axonopus compressus* (Sw.) Beauv.
Poaceae	*Eleusine indica* (L.) Gaertn.
Rubiaceae	*Borreria* sp.
Verbenaceae	*Stachytarpheta jamaicensis* (L.) Vahl

Table A3: Crops grown in the upland of Leyte, Philippines, 2002

Seasonal, grown in patches	
Spring onion	*Allium fistulosum* L.
Cabbage	*Brassica oleracea* L.
Chinese cabbage	*Brassica rapa* L.
Pechay	*Brassica rapa ssp. chinensis* L.
Sweet pepper	*Capsicum annuum* L.
Taro	*Colocasia esculenta* L. Schott
Cucumber	*Cucumis sativus* L.
Squash	*Cucurbita* sp.
Carrots	*Daucus carota* var. *sativus*
Sweet potatoe	*Ipomoea batatas* L.
Tomato	*Lycopersicon esculentum* Mill.
Cassava	*Manihot esculenta* Crantz.
Beans	*Phaseolus lunatus* L.
Eggplant	*Solanum melongena* L
Tannia	*Xanthosoma sagittifolium* L. Schott
Corn	*Zea mais* L.
Perennial, grown in patches	
Abacca	*Musa textiles* Nee.
Chayote	*Sechium edule* (Jaq.) Sw.
Fruits, grown in-between patches	
Pinapple	*Ananas comosus* L. Merr.
Jackfruit	*Arthocarpus heterophyllus* Lam.
Papaya	*Carica papaya* L.
Citrus	*Citrus* spp.
Banana	*Musa x paradisiaca* L.

Table A4: Most deleterious arthropod pest species, Leyte 2001

Agromyzidae	*Liriomyza L. chinensis* (Kato)
Agromyzidae	*Liriomyza sativae* (Blanchard)
Chrysomelidae	*Psylliodes brettinghami* Baly
Chrysomelidae	*Psylliodes balyi* (Jacoby)
Chrysomelidae	*Cassida circumdata* (Herbst.)
Chrysomelidae	*Cylas formicarius elegantulus* (Fabr.)
Chrysomelidae	*Aplosonyx speciosus* Baly
Cicadellidae	*Bothrogonia argyrops* (Signoret)
Cicadellidae	*Bothrogonia ferrugineus* (Fabricius)
Cicadellidae	*Hecalus* sp.
Cicadellidae	*Erythroneura* sp.
Curculionidae	*Philicoptus* sp.
Curculionidae	*Metapocytrus boholensis* Schultze
Curculionidae	*Metialma* sp.
Curculionidae	*Metapocyrtus (Trachycyrtus)* sp.
Pyralidae	*Leucinodes orbonalis* (Guenee)

5. Abundance of selected insect species in natural and agricultural habitats of a tropical upland at Leyte, Philippines

Abstract

The objectives of this study, dealing with the relationships of insects between the natural forest and the open agricultural land, were to: (a) record insects at sites of the forest interior, the forest margin and agricultural land, using modified Malaise traps, in order to identify species that occur in the forest as well as in the open country, (b) determine the movement patterns of selected species based on their abundances at the different habitats, (c) find out whether major pest species of the cultivated crops show any relationship to the adjacent natural forest, and (d) find out whether species originating from the forest (non-pest species) are able to colonize open country.

The results indicate that the habitat of the pest species considered is limited to cultivated land and does not include the forest. None of the non-pest species recorded in this study would be able to exist permanently in the agricultural area. They all depend on a closed forest habitat and therefore will become extinct as the forest disappears with proceeding slash-and-burn agriculture. However, some but not all of the pest and forest species were regularly recorded from the forest margin.

5.1 Introduction

The forests in the humid tropics are dwindling in an alarming rate (Tole 1998, Dudley *et al*. 1998, Laurance *et al*. 2000, Chazdon 2003), and the loss of biodiversity due to the decline of such habitats is a well-known fact (Whitmore & Sayer 1992, Brooks *et al*. 2003). Because of commercial logging activities along with slash-and-burn agriculture, deforestation in tropical SE Asia is one of the most rapid (Laurance 1999, Fu 2003, Giri *et al*. 2003). This is accompanied by the expansion of managed land adjacent to natural habitats. Numerous studies deal with the consequences of forest disturbance and fragmentation for fauna and flora (Watt *et al*. 1997, Didham *et al*. 1998, Bawa & Seidler 1998, Tabarelli *et al*. 1999, Laurance *et al*. 2000, Willott *et al*. 2000, Vasconcelos *et al*. 2000, Davis 2000, Hamer & Hill 2000, Brook *et al.* 2003). In contrast, comparatively few studies focus on the biodiversity of cleared and converted land of formerly forested areas. In many regions of SE Asia, cultivated and degraded land outnumbers by far the natural ecosystems. Therefore, managed landscapes comprising agricultural and fallow land need to be included in the efforts to preserve and restore natural biodiversity. A major challenge for conservation is to understand the capacity of managed habitats to support and conserve biodiversity and in addition, the ability of species to exploit such habitats (Goehring *et al.* 2002). Under this aspect, traditional agroforestry systems such as coffee and cacao plantations have been studied by several authors. Perfecto *et al.* (1996) found that multistrata traditional coffee plantations and natural forests have similar patterns of arthropod diversity. They also reviewed a number of biodiversity studies carried out in shaded coffee plantations in Latin America and concluded that such habitats provide the last refuges for animal species in areas where the original forest cover has disappeared. Similar conclusions were drawn in studies conducted by Moguel & Toledo (1999), dealing with traditional coffee systems of Mexico, and by Rice & Greenberg (2000) dealing with cacao plantations. Klein *et al.* (2002) carried out studies on the influence of land use intensity on arthropods of cacao and coffee agroforestry systems in Sulawesi, Indonesia. They found that species diversity of pollinating bees did not change significantly in relation to land use intensity. However, along a gradient of increasing land use intensity, changes in arthropod community structure were detected. There was an increase of solitary bees and a decrease of social bees. In addition, there was an increase in the abundance of phytophagous insect species and a decrease of entomophagous species, resulting in a significant decrease of the ratio of predators to prey. Klein *et al.* (2002) concluded that, despite minor changes in species diversity, the changes in species abundance indicate changes in the dominant species interactions and, therefore, changes in ecosystem functions.

One of the few studies including both forest and agricultural systems was conducted by Ricketts *et al.* (2001), who recorded moth species from forest fragments and from different surrounding agricultural habitats including coffee, mixed crops and pasture in Costa Rica. No significant difference in moth species richness between different agricultural habitats was evident, but species richness decreased with increasing distance to the forest fragments. It was also found that the majority of moth species frequently moves between forest and agricultural habitats.

Another attempt towards documenting the diversity and movement patterns of insects in a tropical landscape was done by Irwin *et al.* (2000) in Costa Rica. They used Malaise traps to record leaf beetles (Chrysomelidae) and leafhoppers (Cicadellidae) in forest and adjacent pasture land. It was found that most specimens of leaf beetle and leafhopper taxa are distributed sparsely in the forest and move preferentially towards the pasture sites. The study provided supportive evidence that there is a continual and pervasive interchange of species between managed and unmanaged land.

In the studies cited above, several aspects of the insect fauna existing in tropical landscapes including managed habitats have not yet been considered. Most studies focused upon species originating from the forest in order to detect changes in diversity or abundance between different habitat types, but did not specifically consider the margin between the natural forest and the open cultivated country. On the other hand, the insect fauna of such landscapes includes species related to agricultural land, such as pests of crops. The question if such species show any connection with the natural forest or the forest margin, is largely unanswered. In order to study the interchanges of insect species between natural forest and agricultural habitats, we selected localities where natural forest borders upon recently created agricultural land in an upland area of Leyte island, Philippines.

The objectives were to (a) record insects at sites of the forest interior, the forest margin and agricultural land in order to identify species that occur in the forest as well as in the open country and (b) determine the abundances of these species at the different sites and trap positions. These data were used to identify movement patterns of these species in order to find out whether (c) major pest species of the cultivated crops show any relationship with the adjacent natural forest, and (d) species originating from the forest are able to colonize open country.

5.2 Material and methods

Description of study area: The study was conducted in 2001 (Jan-Dec) and 2002 (Apr-Sep) in a slopy watershed area, located at about 800 m asl in the lake Danao region of Leyte island, Philippines (11°05’18’’N; 24°42’35’’E). The climate is typical of a tropical upland area, with a temperature range from 20 to 28 °C and an annual precipitation of about 3500 mm. In the study year of 2001, annual precipitation was only 2778 mm due to El Niño. (climate data of 2002 are not available). There are two seasons of mainly dry periods (Feb–Jun, and Sep-Oct), and two seasons of more or less continuous rainfall (Jul-Aug, and Nov-Jan). Despite the relatively low altitude, the original vegetation is represented by a mossy forest. The average canopy height is about 20 m, with a maximum height of 30 m. Most stems have diameters up to 40 cm in breast height (DBH), but canopy building trees can reach up to 1.5 m DBH. Tree species diversity is high, at least 100 species were recorded. Identification of tree species was based on plots (20 m x 20 m) around the position of the traps in the forest habitat at the research localities. The undergrowth vegetation is very dense, including a variety of climbing plants, ferns, tree ferns and palms.

Due to slash-and-burn activities within the last ten years, formerly forested areas were transformed into cultivated land, including single fruit trees, bushes, fallows and degraded areas. At the border between forest and cultivated land, the forest margin is composed of sparse stands of pioneer tree species such as *Macaranga cf. philippinensis* (Euphorbiaceae) and *Melastoma sp*. (Melastomataceae) and a ground cover dominated by grasses. The cultivated land was composed of small patches (5-50 m^2) of seasonally changing vegetables. The main crops grown were tomato (*Lycopersicon esculentum* Mill.), spring onions (*Allium fistulosum* L.), beans (*Phaseolus lunatus* L.), eggplants (*Solanum melongena* L.) and pechay (*Brassica chinensis* L.). The only perennial vegetable was chayote (*Sechium edule* (Jacq). Sw.). No insecticides and herbicides were applied at the field sites studied.

Field methods and species selection: The study was carried out at two localities of the same slope, at about 1500 m distance from each other. Each locality included three types of habitat, where insect sampling was conducted: (1) the forest interior (at the upper slope) at a distance of about 25 m from the forest margin, (2) the forest margin and (3) vegetable fields at distances between 10 - 27 m from the forest edge, depending on the crop patch position at the lower slope (Fig. 1). Insect sampling was carried out using Malaise traps (Malaise 1937, Townes 1962, 1972), which were modified by installing a second collecting jar, allowing separate records of the individuals approaching the two arrival sides. That is, each of the traps yielded two samples at the same time from two opposite directions. All three traps per locality were installed parallel to each other, along the contour line.

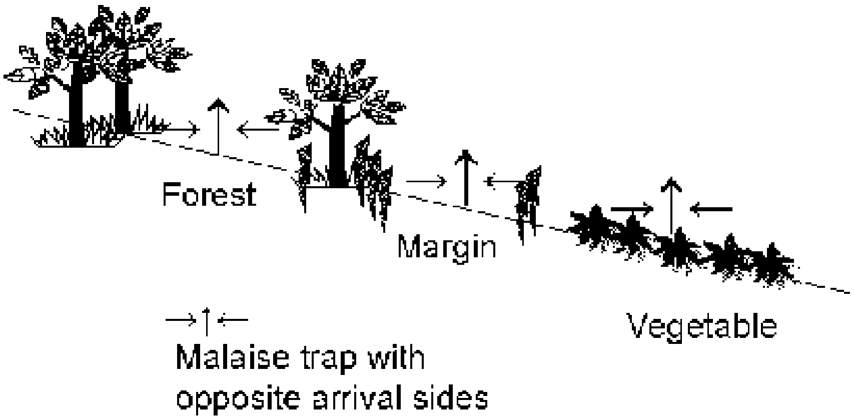

Figure 1: Schematic representation of trap positions and arrival sides of the Malaise traps at the three habitat types.

At both localities, Malaise trapping was carried out twice per month. The collecting jars were filled with 70% alcohol and kept open for 48 hrs, then cleared from the collected individuals. Sampling was carried out over a total period of 18 months (Jan-Dec 2001, and Apr-Sep 2002), yielding a total of 72 samples for each of the six trap arrival sides of the two localities taken together. From each of the samples, the insect specimens were separated according to orders and divided into recognizable taxonomic units (RTU). RTUs represent approximate species, and provide a practical approach to the current, overwhelming problems of taxonomy (Ramsay 1986, Oliver & Beattie 1993, 1996, Hutcheson 1990, Hutcheson & Jones 1999, Hutcheson & Kimberley 1999, Bolger *et al.* 2000). For further analyses, two groups of insects were selected from the samples. The first group (in the following termed as "pest species") included eleven of the major pest species of the crops and fruit trees cultivated. The criteria of selection were based on field observations of crop damage and additional information according to the assessments of farmers. The pest species and their feeding behaviour are presented in Table 1.

Table 1: List of insect pest species considered in this study and their host plants or feeding behaviour, respectively. "Polyphagous" indicates that the species was observed feeding on more than one plant family of crops in the study area.

Family	**Species**	**Host plants / feeding behaviour**
Agromyzidae	*Liriomyza chinensis* (Kato)	*Allium fistulosum* L.
Agromyzidae	*Liriomyza sativae* (Blanchard)	polyphagous
Chrysomelidae	*Psylliodes brettinghami* (Baly)	Solanaceae
Chrysomelidae	*Psylliodes balyi* (Jacoby)	Solanaceae
Chrysomelidae	*Aplosonyx speciosus* (Baly)	Araceae
Cicadellidae	*Bothrogonia argyrops* (Signoret)	polyphagous
Cicadellidae	*Bothrogonia ferrugineus* (Fabricius)	polyphagous
Curculionidae	*Philicoptus* sp.	polyphagous
Curculionidae	*Metapocyrtus boholensis* (Schultze)	polyphagous
Curculionidae	*Metialma* sp.	polyphagous
Curculionidae	*Metapocyrtus* sp.	polyphagous

The second group (in the following termed as "non-pest species") is represented by twelve species which have been recorded more than twice in each of the three habitat types (Table 2) during the total period of records.

Table 2: List of forest insect species considered in this study and their trophic guild

Family	**Species**	**Trophic guild**
Braconidae	*Chelonus* sp.	parasitoid
Cixiidae	*Bennaria* sp.	sap sucker
Dryophthoridae	*Rhabdoscelus* sp.	nectar / pollen feeder
Halictidae	*Homolictus merescens* (Cockerell)	pollinator
Ichneumonidae	*Lissonota* sp.	parasitoid
Ichneumonidae	*Acrolyta* sp.	parasitoid
Pompilidae, Pompilini	*Episyron* sp.	predator
Pompilidae, Pompilini	*Monochares* sp.	predator
Scelionidae	*Scelio* sp.	parasitoid
Scoliidae	*Campsomeris rohweri* (Betrem)	predator
Scoliidae	*Campsomeris aurulenta* (Smith)	predator
Vespidae, Ropalidia	*Ropalidia flavopicta flavobrunnea* (van der Vecht)	predator

All species considered were present during all periods of the study, i.e. no relationships between occurrence and seasonal weather conditions were observed. Furthermore, there were no significant differences between abundances of the selected pest- and non-pest species at the two localities, according to ANOSIM (see data analysis). Therefore, species abundances in the two localities were pooled over the total sample period with respect to habitats and arrival sides. Thus, mean values of the numbers of the selected pest and non-pest species, calculated from the total of the samples per trap arrival side of both localities (n = 72) over the entire sample period of 18 months, were used for data analysis.

Identification of the selected species was carried out as accurate as possible with the help of entomologists from the University Los Baños, Dep. of Entomology, Philippines.

Data analysis: Abundances of pest- and non-pest species at the two localities were compared using one-way pairwise ANOSIM (analysis of similarities, with 5000 permutations; Hammer *et al.* 2001). Multivariate groups were compared by defining distances between groups of selected pest- and non-pest species in the different arrival sides of traps at the two localities for each of the selected species.

Cluster analyses were conducted to (1) identify quantitatively similar groups of the selected pest- and forest species between the trap arrival sides and (2) to identify similarities in the distribution of abundances of these species in the samples, represented by the arrival sides of the traps at the three habitat types. Cluster analyses were based on the Morisita index of similarity (Morisita 1959), being recommended as the best overall similarity measure for abundance data in community analysis (Wolda 1981, Krebs 1998). Among the algorithms for hierarchical clustering, we selected the unweighted pair-group method using averages (UPGMA), which is regularly used in ecology (Wolda 1981, James & McCulloch 1990). Cluster groups representing the quantitative composition of the pest- and forest species at the six arrival sides were tested for significant differences using bootstrapping procedures (Hammer *et al.* 2001). Cluster groups representing the abundances of each of the pest- and forest species from all arrival sides and habitats, were tested for significant differences using one-way pairwise ANOSIM (Hammer *et al.* 2001).

In order to compare abundances of each single species in the opposite arrival sides of each trap, Wilcoxon signed rank test was applied (p<0.5), (Minitab 13; Minitab Inc.).

Data were encoded and processed employing Excel 4.0 (Microsoft Windows XP 2002) and statistical analyses were performed using the software programmes PAST (Hammer *et al.* 2001) and Minitab 13.

5.3 Results

Results of the cluster analysis referring to quantitative similarities of groups of the selected pest species between the trap arrival sides are shown in Fig. 2.

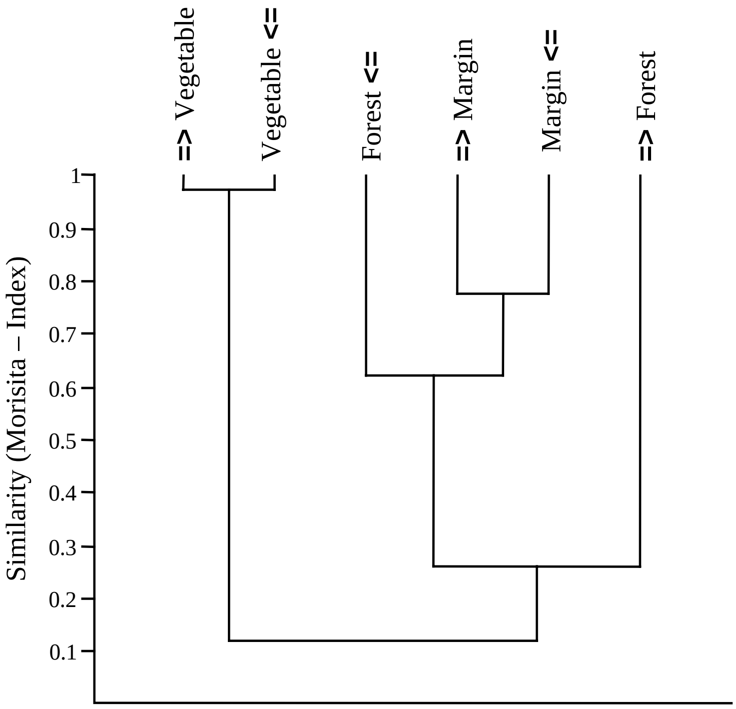

Figure 2: Cluster showing similarities between total abundances of the selected pest species in the opposite arrival sides of the traps at the three habitats. Data represent the mean values of the two localities and of the total number of samples (n = 72). => arrival side open to the forest (or forest interior); <= arrival side open to the cultivated land.

Highest similarity (98%) occurs between the catches of the opposite sides of the vegetable traps, followed by the catches of the opposite arrival sides of the traps located at the margin of the forest with a similarity of 78%. The catches from the field-oriented arrival sides of the forest traps are more similar to the ones from the arrival sides of the margin traps (62%), than to the catches from the arrival sides of the forest traps oriented to the forest interior (28%). The latter have very low similarities to each of the arrival sides of the vegetable traps (12%). Groups defined by cluster analysis showed highly significant differences of mean values between traps of the three habitats ($p<0.01$), as well as between all six arrival sides of the traps ($p<0.05$).

Two distinct groups (1, 2) resulted from the cluster analysis of selected pest species referring to the abundances at arrival sides of traps (Fig. 3).

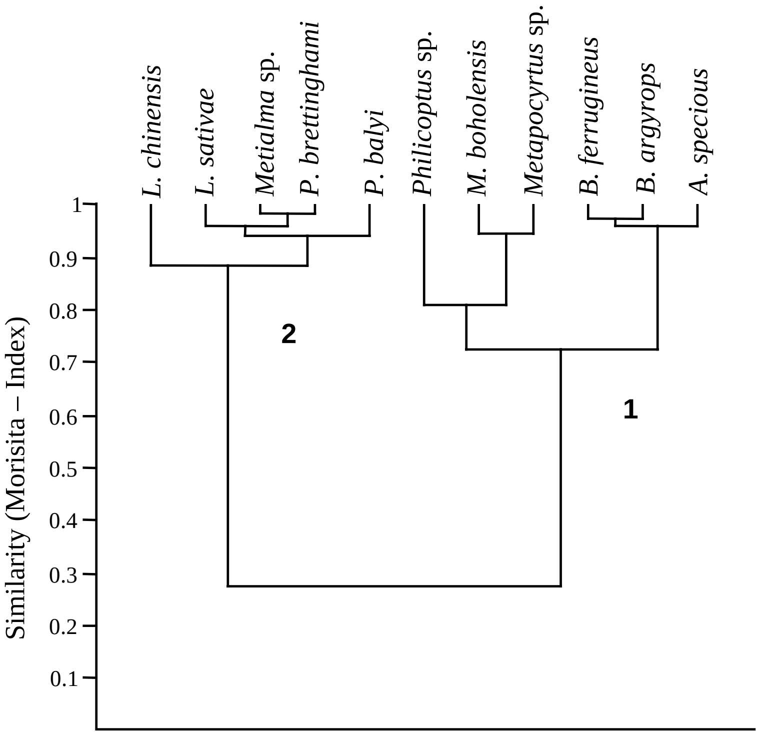

Figure 3: Cluster showing similarities between the total abundance of each of the selected pest species per trap arrival side. Data represent the mean values of the two locations and of the total number of samples (n = 72).

Group 1 and 2 are highly significant different from each other according to one-way ANOSIM (R = 0.99; p = 0.003). Within group 1, abundances of the curculionid beetles *Philicoptus* sp., *Metapocyrtus boholensis* and *Metapocyrtus* sp. on the one hand are not significantly different from the Cicadellidae *Bohtrogonia ferrugineus*, *B. argyrops*, and the Chrysomelidae *Aplosonyx speciosus* on the other (R = 0.81, p = 0.1). A member of group 1 is *Philicoptus* sp., with the mean abundances at the six arrival sides of both locations shown in Fig. 4.

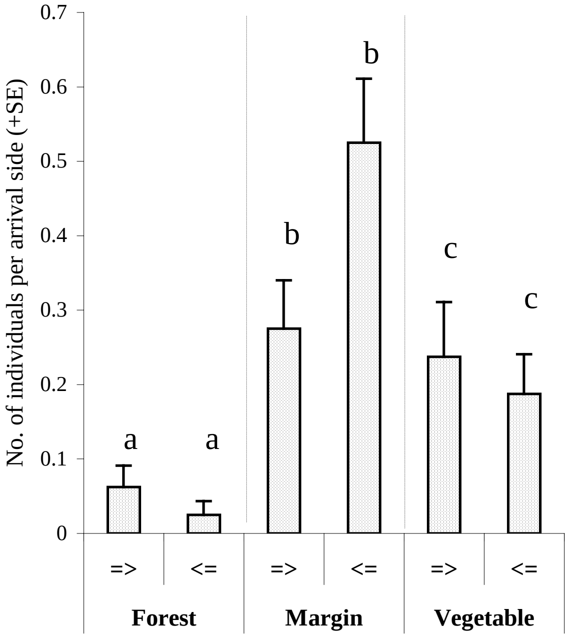

Figure 4: Mean numbers of individuals (+ SE) of *Philicoptus* sp., recorded from the different habitat types and trap arrival sides, respectively. Data represent the total number of samples from both localities (n = 72). Different letters indicate significantly different mean values at p<0.05.

Highest abundances of *Philicoptus* sp. were reached at the two sides of the margin traps, followed by the two sides of the vegetable traps. There are no significant differences at p<0.05 between the opposite arrival sides at any of the three habitats.

The abundances of the Agromyzidae *Liriomyza sativae*, representing group 2, are highest at the vegetable traps (Fig. 5), although the crops grown during the study period were not always host plants of this species.

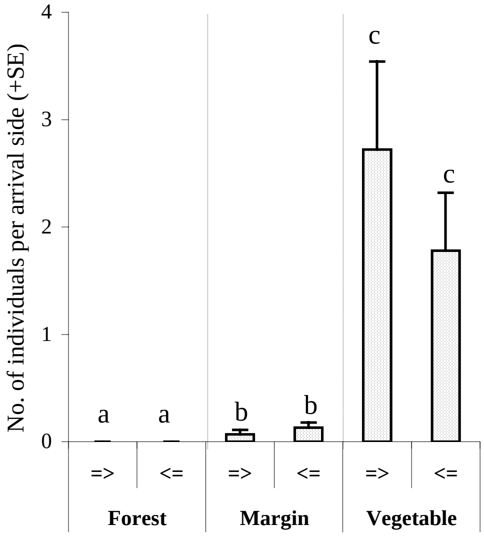

Figure 5: Mean numbers of individuals (+ SE) of *Liriomyza sativae* (Blanchard), recorded from the different habitat types and trap arrival sides, respectively. Data represent the total number of samples from both localities (n = 72). Different letters indicate significantly different mean values at $p < 0.05$.

In contrast, low numbers of this species occurred in the forest- and in the margin traps. There are no significant differences between the opposite arrival sides of any of the traps at the three habitats.

The cluster analysis results referring to quantitative similarities of groups of the selected forest species between the trap arrival sides are shown in Fig. 6.

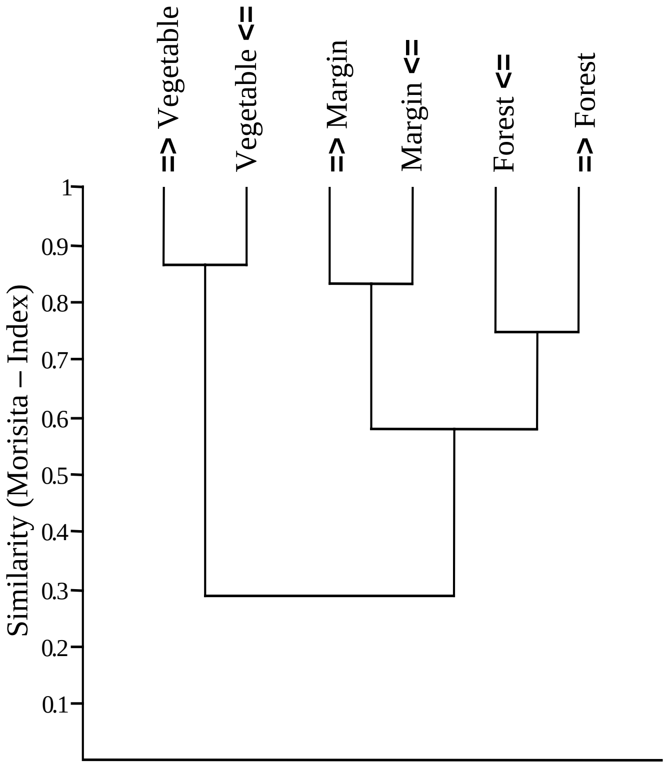

Figure 6: Cluster showing similarities between total abundances of the selected non-pest species in the opposite arrival sides of the traps at the three habitats. Data represent the mean values of the two localities and of the total number of samples (n = 72). => arrival side open to the forest (or forest interior); <= arrival side open to the cultivated land.

Similarity between the catches of the two arrival sides of the vegetable traps is highest (87%), followed by the similarity between the catches of the traps located at the margin of the forest (83%) and the similarity between the catches of the traps located in the forest (74%). Comparison of the habitats shows that the similarity between the catches from the forest and from the margin (59%) is higher than between the catches from either the forest or the margin and the catches from the vegetable (30%). Employed bootstrapping procedures showed significant differences between the three habitats at $p<0.01$.

The cluster resulting from the analysis of the selected non-pest species referring to abundances at the arrival sides of traps is shown in Fig. 7.

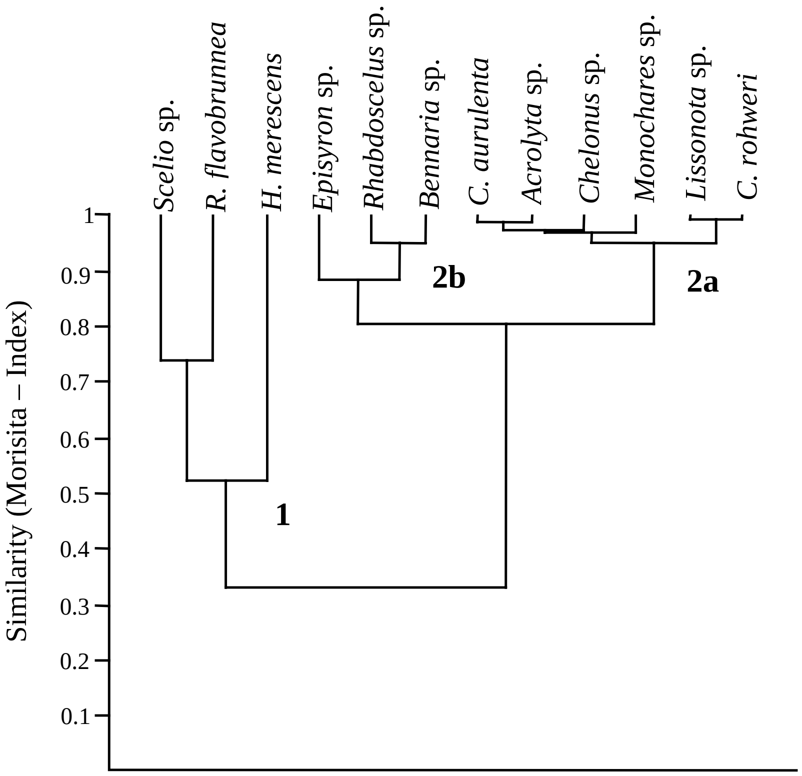

Figure 7: Cluster showing the similarities between the total abundance of each of the selected forest species per trap arrival side. Data represent the mean values of the two locations and of the total number of samples (n = 72).

The two main groups 1 and 2 are highly significant different from each other (R = 0.97; p = 0.005), as well as the two subgroups 2a and 2b (R = 0.94; p = 0.009). The abundances of *Scelio* sp. of group 1 at the different trap arrival sides of the three habitats are shown in Fig 8.

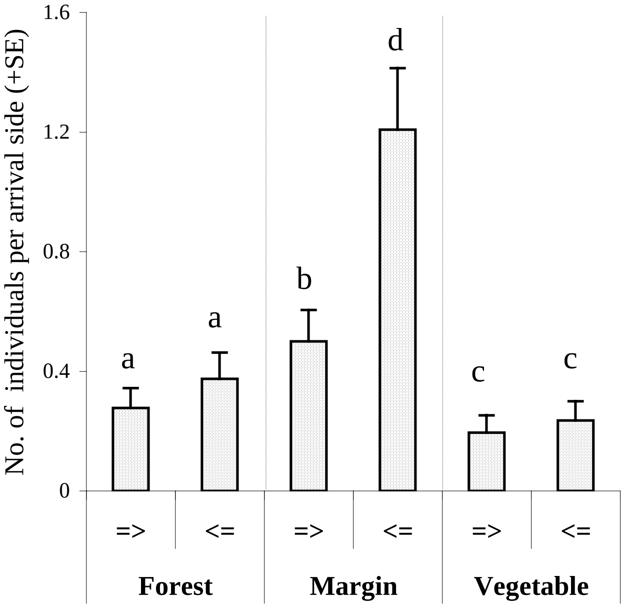

Figure 8: Mean numbers of individuals (+ SE) of *Scelio* sp., recorded from the different habitat types and trap arrival sides, respectively. Data represent the total number of samples from both localities (n = 72). Different letters indicate significantly different mean values at $p<0.05$.

Highest abundances of *Scelio* sp. are reached at the margin habitat. Here the abundances of *Scelio* sp. at the arrival sides open to the vegetable habitat are significantly higher than the abundances at the arrival sides open to the forest habitat ($p<0.05$). The abundances of *Scelio* sp. at the arrival sides of the vegetable- and the forest traps, respectively, were relatively low with no significant differences between opposite arrival sides.

The second member of group 1 is *Homolictus merescens*, with the abundance pattern shown in Figure 9.

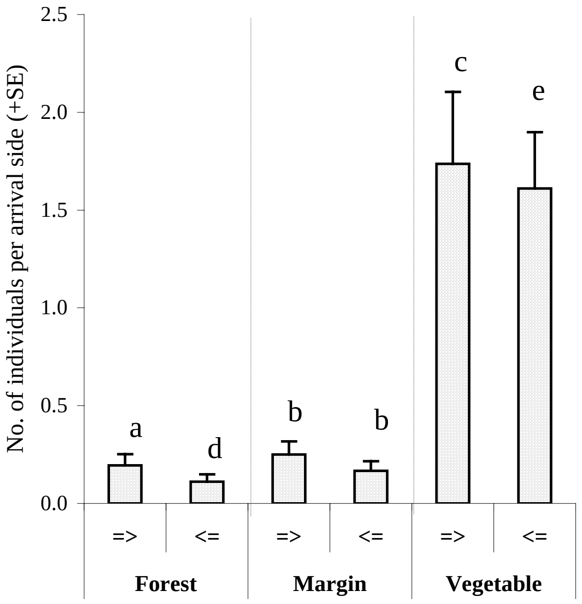

Figure 9: Mean numbers of individuals (+ SE) of *Homolictus merescens* (Cockerell), recorded from the different habitat types and trap arrival sides, respectively. Data represent the total number of samples from both localities (n = 72). Different letters indicate significantly different mean values at p < 0.05.

Abundances of *H. merescens* are clearly highest in the vegetable habitat, with significant differences between the opposite arrival sides of the traps (p<0.05). In contrast, abundances of the bee in the forest and at the margin are very low. There are significant differences between the abundances of *H. merescens* at the opposite arrival sides of the traps at the forest- (p<0.05), but not at the margin habitat. The third member of group 1 is the predatory wasp *Ropalidia flavopicta flavobrunnea*. Fig. 10 shows that no significant differences between the abundances of *R.f. flavobrunnea* at the arrival sides of the traps at any of the three habitat types were found.

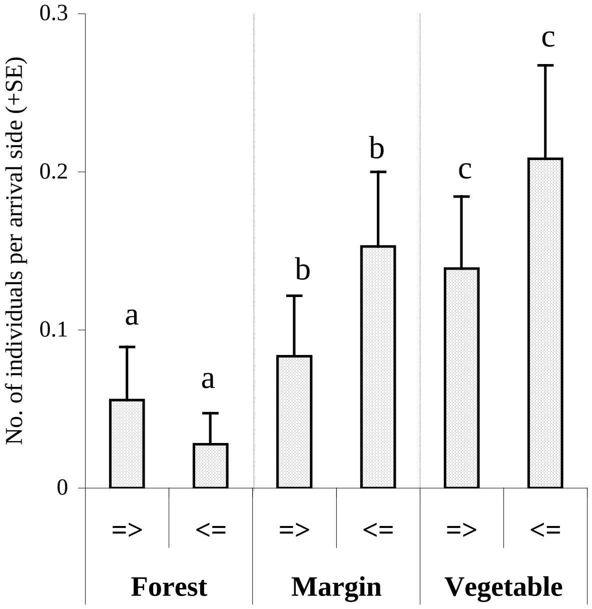

Figure 10: Mean numbers of individuals (+ SE) of *Ropalidia flavopicta flavobrunnea* van der Vecht, recorded from the different habitat types and trap arrival sides, respectively. Data represent the total number of samples from both localities (n = 72). Different letters indicate significantly different mean values at $p < 0.05$.

The abundances of *R. f. flavobrunnea* decrease in the sequence of vegetable, margin and forest habitat.

The abundances of *Lissonota* sp., representing subgroup 2a, decrease in the sequence of forest, margin and vegetable habitat (Fig. 11).

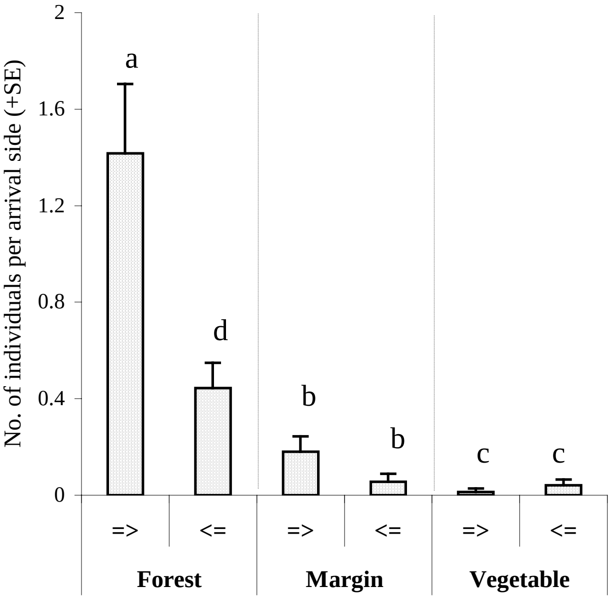

Figure 11: Mean numbers of individuals (+ SE) of *Lissonota* sp. (Ichneumonidae, Banchinae), recorded from the different habitat types and trap arrival sides, respectively. Data represent the total number of samples from both localities (n = 72). Different letters indicate significantly different mean values at $p < 0.05$.

The abundances of the wasp at the opposite arrival sides of the forest traps are significantly different from each other at $p<0.05$.

A representative example of subgroup 2b is *Bennaria* sp., showing a similar distribution of abundances as the species of subgroup 2a, but no significant differences between abundances at the opposite arrival sides of any trap (Fig. 12).

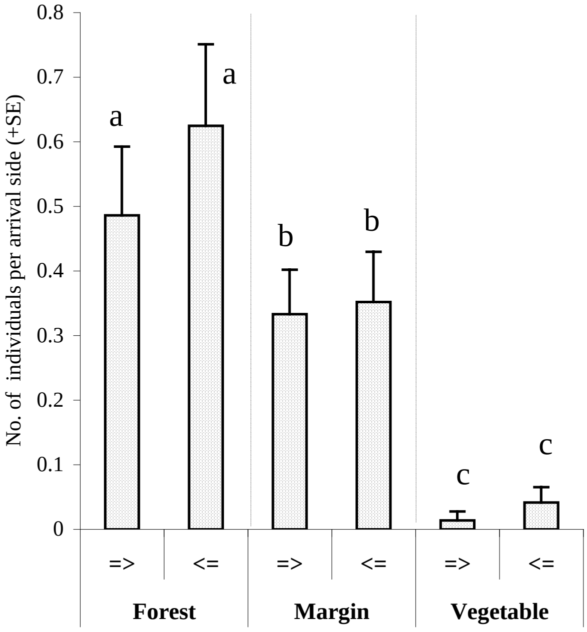

Figure 12: Mean numbers of individuals (+ SE) of *Bennaria* sp. (Hemiptera, Cixiidae) recorded from the different habitat types and trap arrival sides, respectively. Data represent the total number of samples from both localities (n = 72). Different letters indicate significantly different mean values at $p < 0.05$.

5.4 Discussion

The separation of the main groups 1 and 2 of pest species resulting from the cluster analysis (Fig. 3) is related to the differences in abundance between the three habitat types. Members of group 1 were neither caught nor observed in considerable numbers in the forest. Although all these species include major pests that feed on host plants growing in the vegetable habitat, their highest abundances are reached at the margin. Group 2 also includes members of several families. There are one monophagous and one polyphagous leaf miner (Agromyzidae), and three polyphagous beetles (one Curculionidae, two Chrysomelidae). Members of group 2 were neither recorded nor observed in the forest habitat, but in contrast to those of group 1, they were also very rare at the margin and reached highest abundances in the vegetable habitat. Taken together, the results showed that pest species fall into two main groups which are (a) species with a relatively broad habitat spectrum, that also includes the margin habitat, but not the forest (group 1) and (b) species that are largely restricted to the vegetable habitat (group 2). Both groups include specialists as well as generalists and therefore, differences in feeding habits may not explain the differences in abundance patterns between the two groups. However, the most important pests of vegetables were found in group 2, indicating that the preferred host plants occurred in the cultivated area. Species of group 1 obviously prefer host plants growing at the margin.

The results referring to the abundances of the pest species indicate that these species have no relationships to the adjacent natural forest, i.e., none of them originates from this type of habitat. Rather, the selected pest species seem to be introduced with their host plants, or immigrated from the surrounding agricultural land, following the expansion of cultivated areas. According to the results of Irwin *et al.* (2000) from their study in Costa Rica, most of the Chrysomelidae and Cicadellidae preferentially move from the forest to the pasture and rather stay in the pasture site than move back to the forest. Therefore, Irwin *et al.* suggested the forest to be the source of the phytophagous taxa. This is in contrast to the results of the present study, where none of the phytophagous species acting as crop pests showed any comparable movement pattern, i.e., all of those species were very rare in, or absent from, the forest.

The selected non-pest species show a higher variability of abundance patterns at the three habitat types than the selected pest species. Group 1 (Fig. 7) includes three trophic guilds, represented by the parasitoid wasp *Scelio* sp., the predator *Ropalidia flavopicta flavobrunnea* and the pollinator *Homolictus merescens*. *Scelio* sp. shows its highest abundance in the trap at the margin, and much lower abundances in the forest and in the vegetable habitat (Fig. 8). This pattern is very similar to that of the pest species *Philicoptus* sp. from the pest species group 1 (Fig. 4). Both species show higher abundances at the margin traps in the arrival sides open to the vegetable habitat, but only in the case of *Scelio* sp., the difference is significant, indicating a prevailing movement direction from the field towards the forest. Of both *H. merescens* (Fig. 9) and *R. f. flavobrunnea* (Fig. 10), the abundances increase from the forest towards the field. *H. merescens* was commonly observed visiting flowers of crops and wild plants. In the forest- and vegetable traps, significantly higher abundances of this species were found at the arrival sides open to the forest interior than at the arrival sides open to the vegetable. This indicates a prevailing movement direction of *H. merescens* from the forest towards the open area. The low abundances in the forest might be due to the lower availability of flowers compared to the field. Since *H. merescens* is abundant in the natural forest habitat, the latter is assumed to be the habitat of origin.

According to observations, *R. f. flavobrunnea* is searching for prey (lepidopteran larvae) in the vegetable area, at the margin and in the forest. The high abundances in the vegetable habitat (Fig. 10) indicate that searching is most successful there, probably because the vegetation is less dense and a higher prey density is available. According to Kojima (1982), the nests of *R. f. flavobrunnea* are established on trees, thus the species depends on the forest or the margin as reproduction site. Taken together, the non-pest species of group 1 all have different abundances and movement patters between the habitats, but the forest seems to be their habitat of origin.

All forest species of subgroup 2a (Fig. 7) show their highest abundance in the forest habitat, and clearly decrease towards the field.

The abundance of *Lissonota* sp. (Fig. 11) at the forest trap side open to the forest interior is significantly higher than at the opposite arrival side open to the margin and the field, indicating a movement directed towards the field. However, the low abundances at the margin and in the vegetable do not suggest regular movements towards the margin or the agricultural area.

Members of the forest subgroup 2b also decrease in abundance from the forest to the field. They include *Episyron* sp. (Pompilinae), a predator on spiders, *Rhabdocelus* sp. (Dryophthoridae), observed visiting epiphyte flowers, and *Bennaria* sp. (Cixiidae), a polyphagous herbivore. In contrast to subgroup 2a, the species of subgroup 2b are more abundant at the margin than in the forest. Despite this, the original habitat of the three species of subgroup 2b seems to be the forest. However, the species are also able to invade the margin habitat, with a vegetation structure more related to the forest, than to the open field.

From the results referring to the forest species, it can be concluded that there are (a) species which depend on the forest or on trees for nesting sites, but are able to take advantage from open country in the search for food (group 1); (b) species originating from the forest with highest abundances there, which are able to include the margin as a habitat, but not the open country (subgroup 2b); and (c) species which are clearly dependent on a closed forest, and are characterized by a negligible tendency to move towards the margin or the open country (subgroup 2a).

The three hymenopteran species of group 1 represent a negligible low number of all Hymenoptera that can be assumed to exist in the forest. For example, the maximum number of hymenopteran RTUs recorded from a single sample (representing a 48 hrs sample unit) in a forest trap was 70. Referring to this number, the proportion of hymenopteran species recorded regularly outside the forest as well, is 2.1%. However, the total number of RTUs of forest hymenopterans (i.e. the sum of all RTUs of all samples) is expected to be much higher, and therefore, a proportion of three species represents an extremely low number.

Other studies conducted on the distribution of arthropods in tropical landscapes indicate that different taxa show relationships between natural and cultivated habitats, and that diversity or abundance decrease with increasing degree of disturbance. This was true for ground-dwelling insects (Goehring *et al.* 2002), dung- and carrion beetles (Holloway at al. 1992) and moths

(Ricketts *et al.* 2001, Holloway *et al.* 1992). Our study indicates that these results cannot be generalized for all groups of species existing in the forest. Only three species of Hymenoptera were regularly recorded from the agricultural habitat. The other nine species considered in this study, including members of the Coleoptera and Hemiptera, merely occurred in the open country by chance. As these species even represent those observed most frequently outside the forest, it can be assumed that other members of these orders have no relationship to open country habitats at all. We conclude that none of the non-pest species considered in this study would be able to exist permanently in the agricultural area. They all depend on a closed forest habitat and therefore will become extinct, as the forest disappears with proceeding slash-and-burn agriculture.

6. Abundance of selected insect species in vegetable crops of a Philippine upland

Abstract

The study deals with the relationships of insects between perennial and consecutive changing vegetable crops and was conducted in a tropical upland region. Two kinds of habitats were distinguished: (a) frequently disturbed and rotational changing vegetables with simple architecture; (b) rarely disturbed stands of chayote, *Sechium edule* (Jacq.) Sw. (Cucurbitaceae), with complex architecture, representing the only perennial vegetable in the region. The objective was to analyse the impact of changing crop and weed species composition and the agricultural practices (soil preparation, planting, weeding, harvest) applied on the abundance of selected insect species and to find out whether stands of chayote are used as refuge as long as conditions in the seasonal vegetables become unfavourable due to agroecosystem management applied. The insect species investigated include phytophagous specialists and generalists as well as beneficials (predators and pollinators).

It only was possible to generalize movement patterns regarding the significant different or not different abundances of the selected species in the habitats and in the opposite arrival sides of the traps in each habitat. With respect to the population development of the species in relation to cropping patterns and agricultural practices applied no common patterns could be determined.

6.1 Introduction

Annual cropping systems can be described as shifting mosaics of habitats that vary through time and space in their availability and suitability to insects. Changes in the distribution of habitats and non-habitats due to agricultural activities affect arthropod population dynamics, since modification of habitat patterns forces species to move in search for food, shelter and oviposition sites. The importance of spatial dimension and organism movement for ecological dynamics of the entire agroecosystem as well as for management strategies is widely recognized (Jonsen & Fahrig 1997; Tilman & Kareiva 1997; Gustafson 1998; Hanski 1999; Turner et al. 2001; Hannunen 2003). Concerning the economic benefit of crops grown, pest and beneficial organisms come to the fore. The influence of patch characteristics such as dispersion, density and architecture of plants on insect abundance were examined in field studies. Risch *et al.* (1983) reviewed 150 studies dealing with the effects of agroecosystem diversification on the abundance of 198 pest species referring to the effects of increased plant diversity on pest and predator populations. They found that more than 50% of the pest species were less abundant in more diverse systems compared to less diverse systems. The effect of host plant density on a specialist herbivore, *Acalymma vittata*, the stripped cucumber beetle, was investigated by Bach (1980), who found 10 to 30 times higher densities of the beetle in pure stands of cucumber (*Cucumis sativus* L.) compared to mixed cropped fields (cucumber, corn (*Zea mais* L.), broccoli (*Brassica oleracea* var. *italica* Plenck). Bach (1984) also studied the effects of size and diversity of host plant patches on the specialist cucurbit pest *Acalymma innubum*, and found that patch size and numbers of beetles were positively correlated. The author again found significantly higher numbers of *A. innubum* in patches with low plant diversity. In general, there is a good number of studies demonstrating that the abundance of pest species is lower in mixed cropping systems than in pure stands. Further studies focussed on the influence of patch size, isolation and disturbance frequency on density and diversity of generalist and specialist insects. Jonson & Fahrig (1997) found that generalist species richness and abundance increased with increasing landscape diversity and that patch isolation did not affect specialist insects. Concerning insect trophic guilds in a grassland experiment, Siemann *et al*. (1998) concluded that herbivore diversity is more strongly correlated with parasitoid and predator diversity than with plant diversity. Regarding aphid predator populations in wheat, Elliot et al. (1998) compared fields with broad (24.1 x 24.1 km^2), intermediate (4.8 x 4.8 km^2) and small (1.6 x 1.6 km^2) scale and found larger predator populations with decreasing size of crop patches.

Several experiments dealing with the influence of plant quality on insects indicate that phytophagous insects move readily among patches of host plants, spending more time where their food is either more abundant or of higher quality (Kareiva 1982; Parker 1984). The influence of plant structure was examined by Yang (2000), he observed that the movement patterns of a stinkbug, *Podisus maculiventris,* differed with plant surface structure. Studies on the influence of plant structure and architecture on phytophagous insects were reviewed by Lawton (1983). He concluded that there is a decline of phytophagous insect diversity as plant architectural complexity declines. This was confirmed by Borges & Brown (2001) who found that structurally complex pasture sites support more insect species than less complex ones.

Only very few data on insect movement between patches of different crop plants have been conducted. Risch (1981) found that movement patterns of adult Galerucinae beetles primarily account for observed abundance and distribution between pure and mixed cultures.

Comprising existing knowledge, most studies focus on the influence of patch size, plant diversity, density, quality, structure and architecture of crops on selected insect populations, and were carried out mainly in agroecosystems of the temperate zone. There a major impact on the ecosystem is imposed by winter, with no agricultural activity in the field and hibernating arthropods. In the humid tropics, fields are cultivated all year round, fallow times get short or rare and new fields are cleared by slash-and-burn (Angelsen & Kaimowitz 2001; Altieri & Weid 2001). Favourable climatic conditions allow the cultivation of up to three crops within one year and imply frequent disturbance within agricultural cropping systems. Changes of the flora and fauna in tropical agroecosystems largely result from continuous alterations of biotic and abiotic ecosystem components and from agricultural inputs, which also determine the conditions for insects (Rabb 1978; Ferguson 2003). Thus, tropical agroecosystem dynamics of crop plants, pest- and beneficial insects should be of special interest concerning optimised, sustainable management.

There is an obvious lack of fundamental data concerning abundance patterns of insects in tropical landscapes which may contribute to develop a more sustainable management of the cultivated land. The present study was conducted in a tropical upland region where two kinds of habitats were distinguished: (a) frequently disturbed and rotational changing vegetables with simple architecture; (b) rarely disturbed stands of chayote, *Sechium edule* (Cucurbitaceae), with complex architecture, representing the only perennial vegetable in the region.

The objective was to analyse the impact of changing crop and weed species composition and the agricultural practices (soil preparation, planting, weeding, harvest) applied on the abundance of selected insect species and to find out whether stands of chayote are used as refuge as long as conditions in the seasonal vegetables become unfavourable due to agroecosystem management applied. The insect species investigated include phytophagous specialists and generalists as well as beneficials (predators and pollinators).

6.2 Materials and Methods

Study area

The study was conducted in 2001 (Jan-Dez) and 2002 (Apr-Sep) in a slopy watershed area, located at 800 m a.s.l. in the lake Danao region of Leyte island, Philippines (11°05’18’’N; 24°42’35’’E). The climate is typical of a tropical upland area, with a temperature range from 20 to 28 °C and an annual precipitation of about 3500 mm. In 2001, annual precipitation was only 2778 mm due to El Niño. In general, there are two seasons of mainly dry periods (Mar-Jun; Sep-Oct), and two seasons of more or less continuous rainfall (Jul-Aug; Nov-Feb). Despite the relatively low altitude, the original vegetation is represented by a mossy forest.

Due to slash-and-burn activities of the past ten years, formerly forested areas were transformed into cultivated land, which includes crop land, single fruit trees, bushes, fallows and degraded areas. Fields are dominated by about quarterly changing vegetables grown in small patches of about 5–50 m² size.

Vegetable crops and agricultural practices

The vegetables grown within study time at the two sites were chayote, spring onions (*Allium fistulosum* L.) and sweet pepper (*Capsicum annum* L.) at the one site and chayote, spring onions, pechay (*Brassica rapa* L. ssp. *chinensis*), beans (*Phaseolus lunatus* L.) and cabbage (*Brassica oleracea* L. var. *capitata*) at the other site. Usual cropping practice for all vegetables but chayote is the germination in seed beds and planting of seedlings in ploughed soil. Concerning the monoecious, viviparous chayote, germinated berries are planted directly on the ground. All vegetables instead of chayote are weeded regularly, according to weed pressure and man power available. More regular weeding (all the four weeks) is applied to sweet pepper, pechay and cabbage which are especially susceptible to weed competition. The berries of the creeping chayote are produced all year round and harvested if required. Pruning is the only practice applied whereby sprouts are used as vegetable. Concerning spring onions, the first, second and third re-growth is harvested after one month each. The other vegetables are harvested when mature. Crop residues remain in the field after harvest.

The major weed species present belong to the Asteraceae family (*Ageratum conyzoides* L.; *Bidens pilosa* L. and *Crassocephalum crepidioides* (Benth.) S. Moore), and to the Poaceae (*Paspalum conjugatum* Berg.; *Eleusine indica* (L.) Gaertn). No insecticides and herbicides were applied in the fields studied.

Methods and species selection

The study was carried out at two sites of the same slope, bordering upon natural forest in the upper part, at about 1500 m distance from each other. Each site included two types of habitat, where insect sampling was conducted: (1) vegetable plots with consecutive changing crops at distances between 10-27 m from the forest edge and (2) chayote plots at distances between 70–90 m from the forest edge.

Insect sampling was carried out using Malaise traps (Malaise 1937, Townes 1962, 1972), which were modified by installing a second collecting jar to allow separate records of the individuals approaching the two arrival sides. Two traps per site were installed (one trap in the vegetable and one trap in the chayote plots). Traps were aligned parallel to each other, along the contour line. Thus, each of the traps yielded two samples at the same time, one from the arrival side open to the forest and one from the arrival side open to the cultivated area. At both localities, Malaise trapping was carried out twice per month. The collecting jars were filled with 70% ethanol and kept open for 48 hrs, then were cleared from the collected individuals. Sampling was carried out over a total period of 15 months (Apr - Nov 2001, and Apr – Oct 2002).

For further analyses, 15 of the major pest species of the crops and fruit trees cultivated and ten species of the most common, beneficial Hymenoptera were selected. The criteria of selection were based on field observations and additional information according to the assessments of farmers. A list of pest and beneficial species with information on their feeding habits or host plant spectrum (according to own observations) are presented in Table 1. Identification of the selected species was carried out with the help of specialists.

Table 1: Selected pest and beneficial insect species with information on their host plants and feeding behaviour.

Order	Family	Species	Host plant/feeding behaviour
		Pests	
Diptera	Agromyzidae	*Liriomyza L. chinensis* (Kato)	*Allium fistulosum* L.
	Agromyzidae	*Liriomyza sativae* (Blanchard)	*Cucumis sativus* L., *Brassica rapa ssp. chinensis* L., *Phaseolus lunatus* L., *Lycopersicon esculentum* Mill.
Coleoptera	Chrysomelidae	*Aplosonyx speciosus* Baly	*Colocasia esculenta* L. Schott, *Xanthosoma sagittifolium* L. Schott
	Chrysomelidae	*Cassida circumdata* (Herbst.)	*Ipomoea batatas* L. Poir.
	Chrysomelidae	*Cylas formicarius elegantulus* (Fabr.)	*Ipomoea batatas* L. Poir.
	Curculionidae	*Metapocyrtus (H.) boholensis* var. *Semotus* Schultze	polyphagous
	Curculionidae	*Metapocyrtus (Trachycyrtus)* sp.	polyphagous
	Curculionidae	*Metialma* sp.	polyphagous
	Curculionidae	*Philicoptus* sp.	polyphagous
		Psylliodes balyi (Jacoby)	other Solanaceae plants
	Chrysomelidae	*Psylliodes brettinghami* Baly	*Solanum melongena* L. and
Hemiptera	Cicadellidae	*Bothrogonia argyrops* (Signoret)	polyphagous
	Cicadellidae	*Bothrogonia ferrugineus* (Fabricius)	polyphagous
	Cicadellidae	*Erythroneura* sp.	polyphagous
	Cicadellidae	*Hecalus* sp.	polyphagous
	Cixiidae	*Bennaria* sp.	polyphagous
		Beneficials	
Hymenoptera	Braconidae	*Chelonus* sp.	parasitoid
	Halictidae	*Homolictus merescens* (Cockerell)	pollinator on flowering plants
	Ichneumonidae	*Acrolyta* sp.	parasitoid
	Ichneumonidae	*Lissonota* sp.	parasitoid
	Pompilinae	*Episyron* sp.	predator
	Pompilinae	*Monochares* sp.	predator
	Scelionidae	*Scelio* sp.	parasitoid
	Scoliidae	*Campsomeris aurulenta* (Smith)	predator
	Scoliidae	*Campsomeris rohweri* Betrem	predator
	Vespidae	*Ropalidia flavopicta flavobrunnea* van der Vecht	predator on lepidopteran larvae, small flies, beetles etc.

Statistical analyses

The analyses of abundance patterns, independent from the rotational change of vegetable crops, are based on the total numbers of each species per sample and trap arrival side (n = 72) over the entire sampling period of 15 months. Mean abundances and standard errors were calculated.

To analyse the abundances of the selected species in relation to the vegetables grown, the two sites were considered separately. Mean abundances per month were calculated for the two habitats at one of the sites (n = 36). This was done because the rotation of vegetable crops was not identical at both sites.

Differences between mean species abundance of the two arrival sides per trap were tested for significance using Wilcoxon signed rank test ($p<0.5$), (Minitab 13, Minitab Inc.). Differences of species abundances between trap positions (habitats) were compared with Kruskal Wallis test. Data were encoded and processed using Excel 4.0 (Microsoft Windows XP 2002) and statistical analyses were performed using the software programmes PAST (Hammer *et al.* 2001) and Minitab 13.

6.3 Results

Abundance patterns between perennial and consecutive changing vegetables

Liriomyza L. chinensis (Kato) is a monophagous leaf-miner on spring onions (*Allium fistulosum* L.). Highest abundances of the fly were reached in the seasonal vegetable crops which were significantly different from those in chayote ($p<0.05$), (Fig. 1).

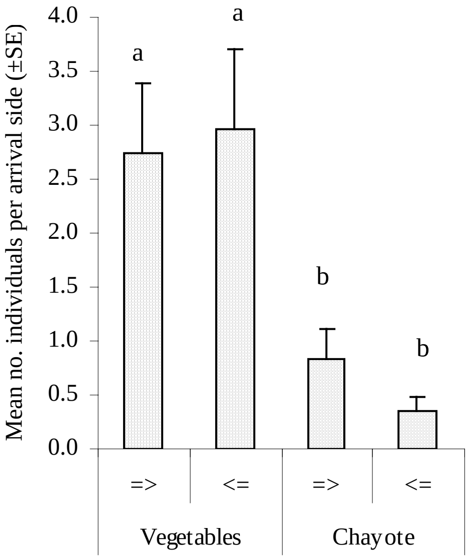

Figure 1: Mean number of individuals (+ SE) of *Liriomyza chinensis* (Kato), recorded from the different habitat types and trap arrival sides, respectively. Data include the total number of samples from both localities (n = 72). Different letters between trap arrival sides indicate differences of mean values at $p < 0.05$. (=> arrival side open to the forest; <= arrival side open to the field)

The abundance of the polyphagous Curculionidae *Philicoptus* sp. was more evenly distributed between habitats (Fig. 2) and there were no significant differences between habitats or arrival sides of traps.

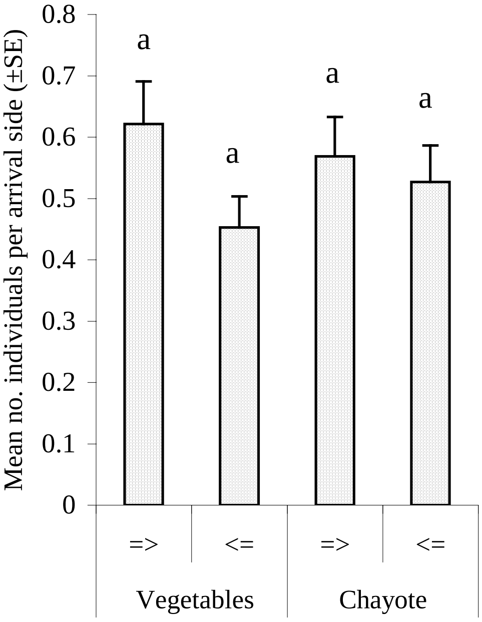

Figure 2: Mean numbers of individuals (+ SE) of *Philicoptus* sp., recorded from the different habitat types and trap arrival sides, respectively. Data include the total number of samples from both localities (n = 72). Different letters between trap arrival sides indicate differences of mean values at $p < 0.05$. (=> arrival side open to the forest; <= arrival side open to the field)

The polyphagous *Hecalus* sp. showed highest abundances within the vegetable habitat, which were significantly different from those in chayote ($p<0.05$; Fig. 3).

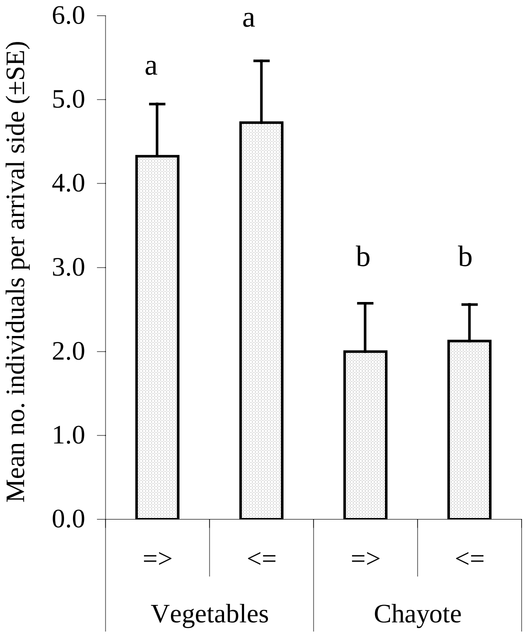

Figure 3: Mean numbers of individuals (+ SE) of *Hecalus* sp., recorded from the different habitat types and trap arrival sides, respectively. Data include the total number of samples from both localities (n = 72). Different letters between trap arrival sides indicate differences of mean values at $p < 0.05$. (=> arrival side open to the forest; <= arrival side open to the field)

There were no significant differences between the mean numbers of individuals of *Hecalus* sp. at the opposite arrival sides at any of the two habitat types.

Concerning the beneficial taxa, the most common observed pollinators within and around the cropped area were *H. merescens.* Highest abundances of the bee were reached within the vegetable habitat (Fig. 4).

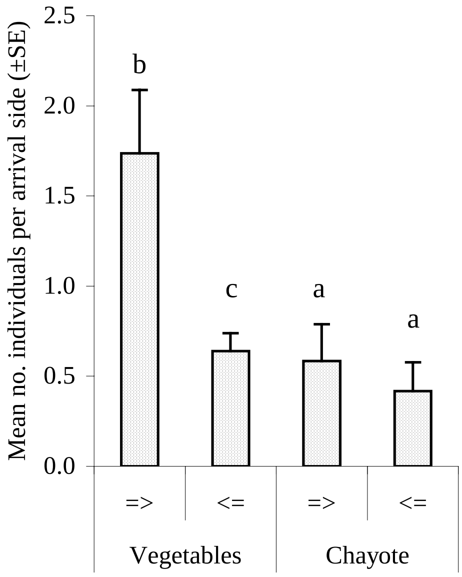

Figure 4: Mean numbers of individuals (± SE) of *Homolictus merescens* (Cockerell)., recorded from the different habitat types and trap arrival sides, respectively. Data include the total number of samples from both localities (n = 72). Different letters between trap arrival sides indicate differences of mean values at $p < 0.05$. (=> arrival side open to the forest; <= arrival side open to the field)

There, abundances in the forest facing arrival sides were significantly higher than in the opposite, field facing arrival sides. Abundances of *H. merescens* decline in the sequence of forest, vegetable and chayote.

Another example of beneficial insect species is the predatory wasp *Ropalidia flavopicta flavobrunnea* van der Vecht. Its abundance was always lower in the forest facing arrival sides of the traps (Fig. 5). There were no significant differences between the mean numbers of individuals of that species at habitats or trap arrival sides.

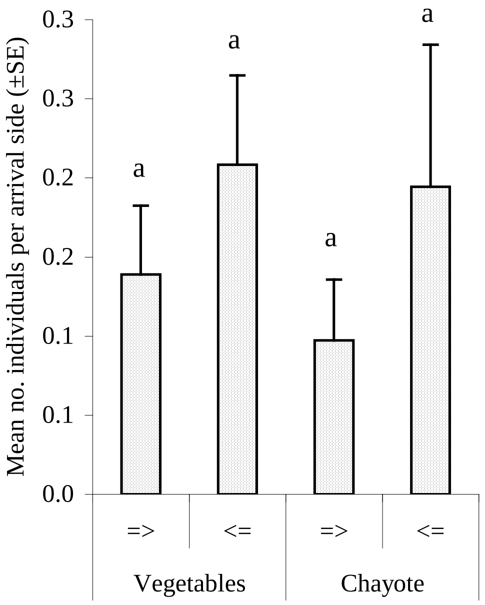

Figure 5: Mean numbers of individuals (± SE) of *Ropalidia flavopicta flevobrunnea* van der Vecht, recorded from the different habitat types and trap arrival sides, respectively. Data include the total number of samples from both localities (n = 72). Different letters between trap arrival sides indicate differences of mean values at $p < 0.05$. (=> arrival side open to the forest; <= arrival side open to the field)

Population dynamics

Figure 6 shows the abundances of *L. chinensis* over 14 months at one of the two sites, where almost exclusively spring onions were grown with the exception of Jul-Nov 2001, when sweet pepper was planted.

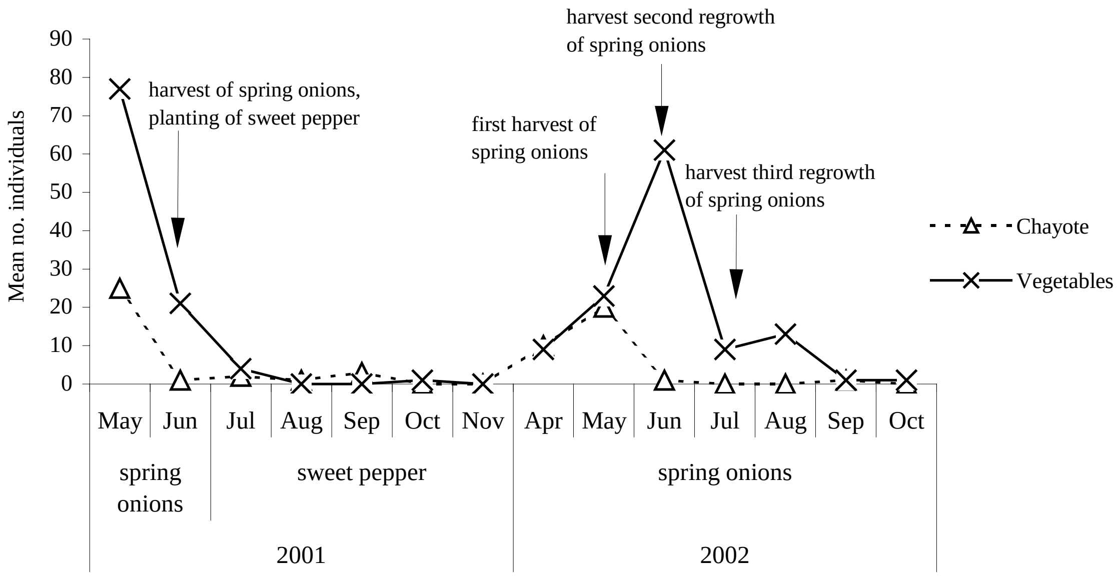

Figure 6: Abundances of *Liriomyza chinensis* (Kato) in two habitats at one location (n = 36) in relation to cropping practices applied, data represent mean monthly abundance.

After the harvest and replacement of spring onions in June 2001, the abundance of *L. chinensis* decreased rapidly and remained at a very low level from July to September 2001, where spring onions only were present in a neighbouring farm within the catchment area. In April 2002, spring onions were newly planted and the abundance of *L. chinensis* increased up to the first and second harvest (May; Jun), then decreased, only slightly recovered up to the harvest of the third regrowth (Aug), and diminished to zero (Sept, Oct).

The population of *H. merescens* within the two years of study at the same site is shown in Fig. 7.

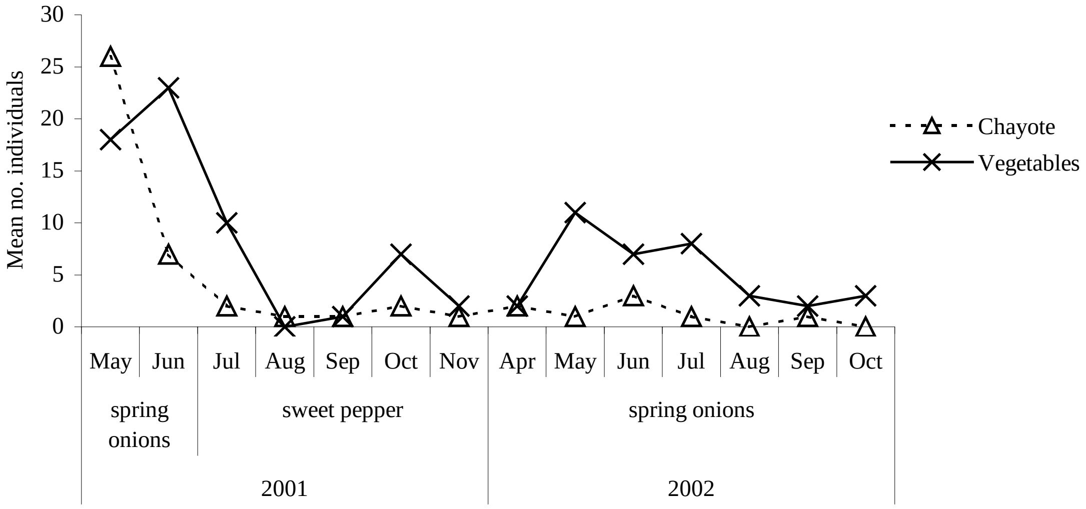

Figure 7: Abundances of *Homolictus* sp. in two habitats at one location (n = 36), data points represent mean monthly abundance.

There, the abundance of *H. merescens* was almost always lower within chayote than in the vegetable rotation.

The population of *Philicoptus* sp. is shown for the other site, where the highest peak was reached in September 2001 in pechay whereby density in chayote was more continuous (Fig. 8). Total beetle abundance was higher in 2001 than in 2002.

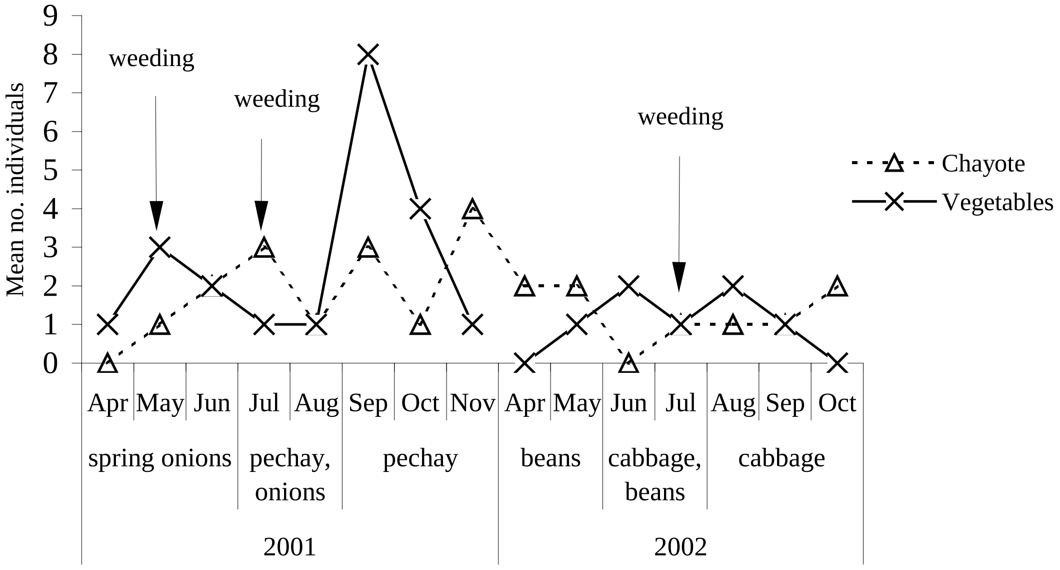

Figure 8: Abundances of *Philicoptus* sp. in two habitats at one location (n = 36) in relation to cropping practices applied, data points represent mean monthly abundance.

The population of *Hecalus* sp. showed peak abundances in August and October 2001 in onions and pechay in contrast to the lower, but also erratic occurrences in chayote (Fig 9). Total abundances were higher in 2001 than in 2002.

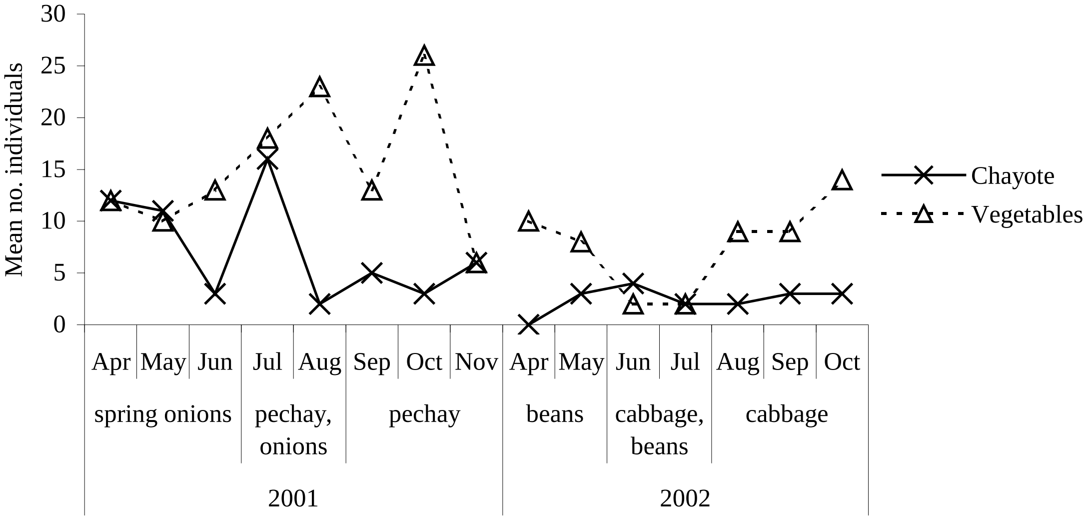

Figure 9: Abundances of *Hecalus* sp. in two habitats at one location (n = 36), data points represent mean monthly abundance.

Regarding population dynamics of the predatory *R. f. flavobrunnea* (Fig. 10), there was a very high peak in July 2001 in chayote and another one in September 2002 in cabbage. Mean numbers of individuals caught in the two habitats changed erratically.

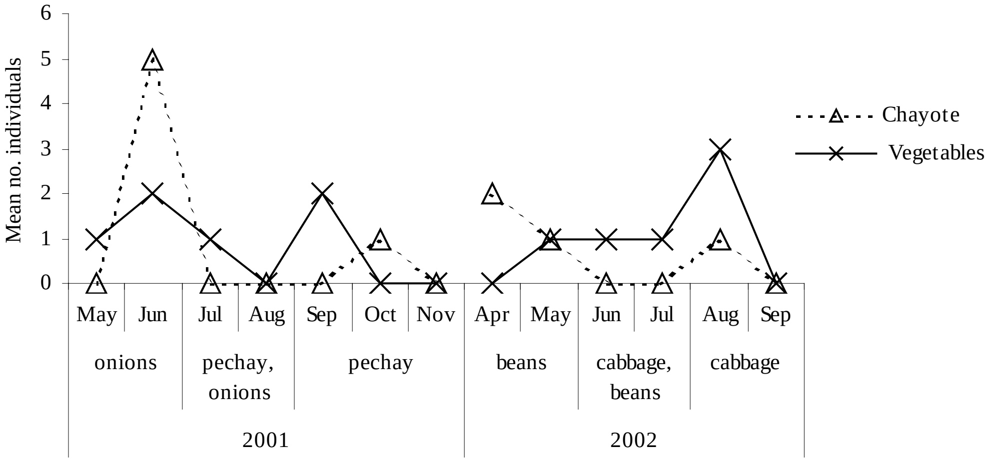

Figure 10: Abundances of *Ropalidia flavopicta flavobrunnea* van der Vecht in two habitats at one location (n = 36), data points represent mean monthly abundance.

6.4 Discussion

Results given in figures 2 and 3 revealed that abundance and population dynamics of *L. chinensis* are related to the presence of its host crop, spring onions. According to observations *L. chinensis* prefers young shoots for oviposition. It can be assumed that the preference of *L. chinensis* for selected shoots is due to the differing surface structure of onion leaves. As noticed, older leaves have a harder cuticle than younger ones. The latter might be difficult to penetrate for oviposition and mining of the larvae. This is confirmed by results of Wei *et al*. (2000), who examined the influence of leaf tissue structure on host feeding selection by female pea leaf miners (*Liriomyza huidobrensis*) on 47 plant species. They found that thickness of epidermis wall and densities of the palisade and spongy tissues of the host plant can act as a physical barrier to female oviposition. The same is probably true for the leaves of spring onions and *L. chinensis*. Furthermore Wei *et al.* assumed that densities of the palisade and spongy tissues affects mining of the larvae as well. In addition, Scheirs *et al*. (2003) worked on host nutrition quality and host plant choice of two Agromyzidae (*Chromatomyia milii, C. nigra*) grass miners and found a negative correlation between pupal size and lignin content of leaves. In summary, peak abundances of *L. chinensis* in the first and second growth of spring onions can be explained by the higher numbers of young shoots in these crop stages, providing favourable conditions for egg deposition and mining of the larvae.

Abundances of *Philicoptus* sp. can be related to the cropping cycle and to the presence of certain weeds. The polyphagous curculionid beetle feeds upon young shoots, leaves and flowers of herbaceous plants. However, based on observations in the field and in feeding trials, the species preferred young crop plants of pechay (*Brassica chinensis* L.) and even more young plants and buds of the two weed species *Ageratum conyzoides* L. and *Crassocephalum crepidioides* (Benth.) S. Moore. These weeds need 8-9 weeks from emergence to first flower initiation (Kranz *et al.* 1977). Abundance peaks of *Philicoptus* sp.

occurred 8-9 weeks after weeding and planting, when pechay seedlings were still small and *A. conyzoides* as well as *C. crepidioides* plants had emerged (Sep 2001) and only correlated with the emerging *A. conyzoides* and *C. crepidioides* after weeding (May 2001; Jun, Aug 2002). Thus abundance peaks can be correlated with the availability of high quality food plants, being young, soft pechay and *A. conyzoides* and *C. crepidioides* plants. Bach (1984) points out, that differences in abundances and tenure times of herbivorous insects result from variation in plant quality. Gratton & Denno (2003) assessed changes in the strength of bottom-up (plant quality) and top-down (predator) impacts on planthopper populations, which responded positively to increased plant quality.

The presence of weeds in the field can increase herbivore populations by decreasing the damage on the crop plants as it was shown by Altieri & Schmidt (1986) who studied flea beetle (*Phyllotreta cruciferae* Goeze) dynamics in collards and found less flea beetles on crops which were associated with weeds. In this context it should be further examined, if the damage of *Philicoptus* sp. on the crop pechay might be reduced by growing *A. conyzoides* and *C. crepidioides* in the same field.

Philicoptus sp. is unable to fly (nonvolant). Since hoeing and weeding directly defines the conditions of the soil surface and plant density, it indirectly affects the spatial distribution of *Philicoptus* sp. The smoother soil surface and reduced plant density after weeding facilitated movement for the flightless weevil, which was also observed by Schotzko & Quisenberry (1999) concerning the pea leaf weevil (*Sitona lineatus* (L.)). Thus the probability for emigration from the weeded area is higher after weeding which means a decrease in abundance. This decrease could be correlated with an increase in the more dense chayote stands in 2001 (May, Jul), but not in 2002 (Jul). Thus it does not seem that the beetle uses chayote as refuge.

The polyphagous pest *Hecalus* sp. occurs most frequently in the consecutive changing vegetable habitat, where mean abundance is significantly higher than in chayote (Fig. 5). The abundance peaks in the vegetables are largely opponent to those in chayote (Fig. 6). Therefore it can be assumed that *Hecalus* sp. uses chayote as refuge, but the underlying mechanisms remain unclear, since no preferences for any plant or plant organs could be observed. It was noticed by Kareiva (1983), Stanton (1983) and Power (1990, 1992) that homopteran insects are not more abundant in dense host plant stands, what is stated with the lower abundance of *Hecalus* sp. in the dense chayote compared to the simple structured, open vegetables. According to Power (1992) leafhoppers were most likely to emigrate from plots with uniform plant dispersal pattern, as examined under experimental conditions. This was not confirmed by our results, based on natural field conditions, showing increasing abundance of *Hecalus* sp. in the uniform, open cabbage plantings compared to the continuous but low abundance in the dense chayote plot (Fig. 6). Thus, the abundances of *Hecalus* sp. did not show any correlation to planting, harvest, weeding or the presence or absence of weed species, which does not indicate any host preference but a general higher tendency for the consecutive changing vegetables.

Regarding the beneficials, *Homolictus* sp. was observed to be the main pollinator of crops and wild plants in the study area. The abundance of the bee in the rotating vegetables is resource oriented, with abundance peaks at the time of main flower supply (Jun, Oct 2001, full bloom of vegetable crops; May 2002, full bloom of several weed species), (Fig. 8). On the perennial chayote there are constantly few flowers present and also the abundance of *Homolictus* sp. was balanced instead of the very high peak in May 2001. At that time, a higher number of flowers was offered due to good weather conditions at that time. Similarly, Shelly & Villalobos (2000) found that three species of Halictidae bees forage in a manner that increases the rate of pollen delivery to developing larvae, preferring newly opened flowers. Chayote can be assumed to represent an important habitat for the maintenance of the pollinator population. Weeding as well as planting affected the occurrence of *Homolictus* sp. only indirectly by defining the flowering time of the emerging weeds and crops.

According to Kojima (1982), *R. f. flavobrunnea* is considered to be a common natural enemy of insect pests on Leyte. The abundance of *R. f. flavobrunnea* in the vegetable rotation is correlated with the infestation of the crops with potential prey, but not with planting, harvest or weeding of the plot. In July 2001, pechay was highly infested with diamond back moth (*Plutella xylostella* L.), in September 2002 the cabbage with cabbage moth (*Crocidolomia binotalis* (Zeller)) The larvae of both species are a common food source of the predator. In addition, cabbage heads have a large surface which is easy to search for potential prey insects and cabbage fields are clearly arranged and easy to scan for the wasp. Although the wasp is of small size (0.7 cm length), this is in concordance with the "hunting efficiency hypothesis" (Morse 1980; Heck & Crowder 1991) which states that vegetation structure changes the efficiency of different hunting strategies and, consequently, (large) predators may be more efficient in sparse vegetation. Similar results were obtained by Costello & Daane (1998); Hatley & MacMahon (1980) and Rypstra (1983) concerning spiders and by Dennis *et al*. (1997) concerning Staphylinid beetles. In contrast, Brose (2003) found more predator species (large Carabidae) in dense vegetation than in structurally simple plant stands.

The examples given provide an insight into the complex coherences of the single species with their environment, the biotic, abiotic and human influences. The present study only considered two defined habitats with the main impact factors being planting, weeding and harvest, which affect by the presence or absence of crops, weeds and soil preparation.

Concerning selected insect species, it only was possible to generalize movement patterns regarding the significant different or not different abundances in the habitats and in the opposite arrival sides of the traps in each habitat. With respect to the population development of the species in relation to cropping patterns and agricultural practices applied no common patterns were found. This might be also due to the limited time frame of the study which did not consider possible further influences by e.g. the vegetation at field- and forest margin, different crop rotations and the macro and micro-climate within the area concerned. Table 2 summarizes the results concerning the impacts of agricultural practices, the presence or absence of weeds and the possible utilization of chayote as refuge.

Table 2: Feeding behaviour, influence of agricultural practices and function of habitats for selected arthropod species, (yes) = no direct impact on insect species.

Species	**feeding behaviour**	**influenced by agricultural practices**	**influence of presence/ absence of weeds**	**employing chayote as refuge**
L. chinensis	monophagous	yes	no	no
Philicoptus sp.	polyphagous	yes (yes)	yes	no
Hecalus sp.	polyphagous	no	no	yes
Homolictus sp.	pollinator	(yes)	yes	no
R.f. flavobrunnea	predator	(yes)	(yes)	no

For none of the species the same or similar pattern could be shown. According to Risch (1981), Boatman (1994) and Altieri (1999), practical issues of agroecosystem design and more theoretical questions of plant-herbivore coevolution depend on knowing exactly what ecological processes result in reduced herbivore loads.

7. General Discussion

Malaise traps as used in this study mainly trap ground moving, low flying (up to trap height), and emerging arthropods, thus focus on chiefly mobile arthropod species (Townes 1962, 1972; Hutcheson & Kimberley 1999, Hutcheson & Jones 1999, Butler et al. 1999). So, although numerous flightless RTUs were trapped, the sampling method most probably underestimated the abundance of the arthropod fauna (e.g. arthropods predominantly living in the canopy or in the soil). In order to attain representative samples, yellow pan traps were placed along the separating middle net of the malaise traps during the first four samplings. This is recommended in the literature (Duelli et al. 1999) for including the species which have the habit to let them fall down when they feel in danger and less mobile species. But since no additional RTUs and/or numerous individuals of specific RTUs were trapped, yellow pan traps were not longer used. Due to restricted man-power and laboratory facilities available no further methods (e.g. pitfall traps, canopy fogging, photo eklekor) were tested or employed. However, in comparison to other, single used trap types or methods, malaise traps provide a remarkably broad range of RTUs, thus are appropriate for basic arthropod surveys.

Analysis of vegetation in the forest and at the forest margin was restricted in terms of determination of genus because of a lack of detailed taxonomic literature. Guides up to species level are hardly available or not existent since the tropical vegetation at the research area is not sufficiently explored yet. The same counts for the determination of arthropod species, where common species might be classified, but the less abundant species only can be assigned to family or genus level.

Concerning **the characterisation of arthropod diversity and community composition along the transect from the natural through the agricultural systems;** it is first referred to the significant differences of arthropod diversity between arrival sides. These were found between the composition of insect communities approaching the corresponding arrival sides of the traps in the forest, at the edge of the forest and in chayote. Differences between insect communities at the edge of the forest are due to margin effects and will be discussed later. Concerning the vegetable habitat the similar arthropod communities were dominated by agricultural pests, which concentrate on their food source, the vegetable crops. The perennial chayote is not visited by specific arthropod pests and provides shelter for various RTUs. Differences between corresponding arrival sides might reflect the intention of RTUs to move towards the forest, their native habitat, or towards the open, the agricultural land. There is no explication from the literature for the highly significant differences in the forest interior. Since no other influence could be identified, we assume, that even inside the forest the movement direction towards the deeper forest or towards the agricultural land has an influence on arthropods in this habitat.

In the present study the main reason for the decrease of the total arthropod diversity towards the field was assumed to be the loss of micro habitats towards the agricultural land. In the forest the vegetation is composed of trees, bushes, ferns, epiphytes and underground vegetation which in total provides a manifold structure of plant organs from the bottom up to the canopy, thus a high number of micro habitats. In the agricultural land a smaller number of habitats is composed by similar crop plants and weeds. Similarly, Schulze et al. (2004), regarding Lepidoptera and Beck (2002), regarding geometrid moth, reported a decrease in diversity from the forest towards the field in tropical landscapes. Beck (2002) related the loss of geometrid species in the modified habitats of the agricultural land to a loss of (micro-) habitats.

Only concerning the mean number of Lepidoptera RTUs along the habitat gradient, our results show merely small differences between forest and agricultural land, whereby the RTUs from the forest were not the same as the RTUs from agricultural habitats. The loss of forest Lepidoptera RTUs, due to habitat loss probably is compensated by an increase of other RTUs which follow the crop plants as e.g. the pink eggplant borer, *Leucinodes orbonalis* (Guenee). However, regarding all arthropod RTUs, the loss of arthropod species from the forest towards the field cannot be compensated by the immigration of new species, as shown by the decrease of the total diversity along this gradient.

Arthropod diversity, number of individuals and RTUs were highest in samples taken at the forest margin. Major et al. (2003) and Majer et al. (1999) found that interior sites (inner forest) tended to have fewer species and individuals than edge habitats, when examining arboreal insects in south-eastern Australia. Bedford & Usher (1994) achieved similar results for the temperate climate, when they investigated the distribution of arthropod species (Carabidae and Aranea) across the margins of farm woodlands in Scotland. Reasons for the higher diversity of margin habitats might be their characteristics: Arthropods move from one habitat to another in their search for food, shelter and suitable breeding sites. Consequently, individuals of all adjacent habitats can be caught at the margin. The forest margin in the present study is characterised by its own vegetation (pioneer species and grasses) which extends about 5-15 m in width. The influence from abiotic (changes in the environmental conditions, temperature, microclimate, (further described by Matlack 1993), direct (changes in the abundance and distribution of species) and indirect (changes in species interactions) biological edge effects as classified by Murcia (1995) may be responsible for this situation. Due to these effects, various microhabitats might be developed and used by specialised species as e.g. were found by Bedford & Usher (1994). In conclusion, the high diversity in the forest margin is due to its position as a transitional zone, where individuals of adjacent habitats as well as specialized species are present.

Hutcheson & Kimberley (1999) in their research used malaise traps and sampled more predacious and less herbivorous beetles in podocarp, broadleaf forest sites compared to heathland and shrubland sites. They explained differences in the distribution of trophic guilds with the influence of habitat processes (e.g. changes in plant physiology due to environmental stress) on abundance and composition of dominant arthropod species within local communities. The appearance of more predacious and less herbivorous arthropods in the forest compared to open land is similar to the results presented here.

Oksanen et al. (1981), Oksanen (1990a, b) and Fretwell (1977, 1987) tried to explain the distribution of trophic guilds between habitats by formulating a theory (OF-theory). The theory says, that in natural stands of productive vegetation food webs develop in which activity of herbivores is consonantly restricted by resident or visiting populations of carnivores or parasites. The theory asserts that in ecosystems with very low productivity, there is not enough food to sustain a second or third trophic level. Applied to the presented results, the forest can be regarded as “natural stand of vegetation” with high productivity. There, a higher percentage of parasitoids and predators restricts the phytophagous insects to a lower percentage than in arable fields, which have a comparably low productivity compared to the forest habitat. The consecutively disturbed vegetable and chayote plots correspondingly had a higher percentage of phytophagous insects.

Beside productivity of vegetation, vegetation structure might further explain the distribution of trophic levels between habitats. Russel (1989) found that the control of populations by natural enemies can be stronger in structurally diverse vegetations. This would be conform with the OF-theory if we assume that more diverse structure also means high plant diversity which could offer more food, shelter and breeding sites. This would be applicable to the present results, where structural diversity and ratio of parasitoids and predators to phytophagous individuals declines from the forest towards the field (margin excluded). Taken together, habitat processes, aspects of the OF-theory as well as the dissimilar vegetation structure seem to account for the distribution of trophic guilds at the research area.

In summary it was found that plant diversity, vegetation structure and taxonomic composition as well as differences in the turnover and productivity of the vegetation at habitats influence arthropod species and groups, thus the arthropod community in the research area.

Concentrating on **abundance patterns of selected species in natural and agricultural systems** the selected pest- and non-pest species were sorted by cluster analysis in two main groups each. The separation of the groups 1 and 2 of pest species is related to the differences in abundance between the three habitat types. Group 1 represents species with a relatively broad habitat spectrum, that also includes the margin habitat, but not the forest. Group 2 includes species that are largely restricted to the vegetable habitat. Both groups include specialists as well as generalists and therefore, differences in feeding habits may not explain the differences in abundance patterns between the two groups. However, the most important pests of vegetables were found in group 2, indicating that the preferred host plants occurred in the cultivated area. Species of group 1 obviously prefer host plants growing at the margin.

The results referring to the abundances of the pest species indicate that these species have no relationships to the adjacent natural forest, i.e., none of them originates from this type of habitat. Rather, the selected pest species seem to be introduced with their host plants, or immigrated from the surrounding agricultural land, following the expansion of cultivated areas. According to the results of Irwin *et al.* (2000) from their study in Costa Rica, most of the Chrysomelidae and Cicadellidae preferentially move from the forest to the pasture and rather stay in the pasture site than move back to the forest. Therefore, Irwin *et al.* suggested the forest to be the source of the phytophagous taxa. This is in contrast to the results of the present study, where none of the phytophagous species acting as crop pests showed any comparable movement pattern, i.e., all of those species were very rare in, or absent from, the forest.

The selected non-pest species show a higher variability of abundance patterns at the three habitat types than the selected pest species. Group 1 includes three trophic guilds, represented by the parasitoid wasp *Scelio* sp., the predator *Ropalidia flavopicta flavobrunnea* and the pollinator *Homolictus merescens*. The abundance pattern of *Scelio* sp. is very similar to that of the pest species *Philicoptus* sp.. Both species show higher abundances at the margin traps in the arrival sides open to the vegetable habitat, but only in the case of *Scelio* sp., the difference is significant, indicating a prevailing movement direction from the field towards the forest. Of both *H. merescens* and *R. f. flavobrunnea*, the abundances increase from the forest towards the field. *H. merescens* was commonly observed visiting flowers of crops and wild plants. In the forest- and vegetable traps, significantly higher abundances of this species were found at the arrival sides open to the forest interior, which indicates a prevailing movement direction of *H. merescens* from the forest towards the open area. The low abundances in the forest might be due to the lower availability of flowers compared to the field. Since *H. merescens* is abundant in the natural forest habitat, the latter is assumed to be the habitat of origin.

According to observations, *R. f. flavobrunnea* is searching for prey (lepidopteran larvae) in the vegetable area, at the margin and in the forest. The high abundances in the vegetable habitat indicate that searching is most successful there, probably because the vegetation is less dense and a higher prey density is available. According to Kojima (1982), the nests of *R. f. flavobrunnea* are established on trees, thus the species depends on the forest or the margin as reproduction site. Taken together, the non-pest species of group 1 all have different abundances and movement patters between the habitats, but the forest seems to be their habitat of origin.

All forest species of subgroup 2a show their highest abundance in the forest habitat, and clearly decrease towards the field. The abundance of *Lissonota* sp. at the forest trap side open to the forest interior is significantly higher than at the opposite arrival side, indicating a movement directed towards the field. However, the low abundances at the margin and in the vegetable do not suggest regular movements towards the margin or the agricultural area.

Members of the forest subgroup 2b also decrease in abundance from the forest to the field. They include *Episyron* sp. (Pompilinae), a predator on spiders, *Rhabdocelus* sp. (Dryophthoridae), observed visiting epiphyte flowers, and *Bennaria* sp. (Cixiidae), a polyphagous herbivore. In contrast to subgroup 2a, the species of subgroup 2b are more abundant at the margin than in the forest. Despite this, the original habitat of the three species of subgroup 2b seems to be the forest. However, the species are also able to invade the margin habitat, with a vegetation structure more related to the forest, than to the open field.

From the results referring to the forest species, it can be concluded that there are (a) species which depend on the forest or on trees for nesting sites, but are able to take advantage from open country in the search for food (group 1); (b) species originating from the forest with highest abundances there, which are able to include the margin as a habitat, but not the open country (subgroup 2b); and (c) species which are clearly dependent on a closed forest, and are characterized by a negligible tendency to move towards the margin or the open country (subgroup 2a).

The three hymenopteran species of group 1 represent a negligible low number of all Hymenoptera that can be assumed to exist in the forest. For example, the maximum number of hymenopteran RTUs recorded from a single sample (representing a 48 hrs sample unit) in a forest trap was 70. Referring to this number, the proportion of hymenopteran species recorded regularly outside the forest as well, is 2.1%. However, the total number of RTUs of forest hymenopterans (i.e. the sum of all RTUs of all samples) is expected to be much higher, and therefore, a proportion of three species represents an extremely low number.

Other studies conducted on the distribution of arthropods in tropical landscapes indicate that different taxa show relationships between natural and cultivated habitats, and that diversity or abundance decrease with increasing degree of disturbance. This was true for ground-dwelling insects (Goehring *et al.* 2002), dung- and carrion beetles (Holloway at al. 1992) and moths (Ricketts *et al.* 2001, Holloway *et al.* 1992). Our study indicates that these results cannot be generalized for all groups of species existing in the forest. Only three species of Hymenoptera were regularly recorded from the agricultural habitat. The other nine species considered in this study, including members of the Coleoptera and Hemiptera, merely occurred in the open country by chance. As these species even represent those observed most frequently outside the forest, it can be assumed that other members of these orders have no relationship to open country habitats at all. We conclude that none of the non-pest species considered in this study would be able to exist permanently in the agricultural area. They all depend on a closed forest habitat and therefore will become extinct, as the forest disappears with proceeding slash and burn agriculture.

The following part of the discussion deals with **abundance patterns of selected species within the agricultural land**. Abundance and population dynamics of *L. chinensis* are related to the presence of its host crop, spring onions. According to observations *L. chinensis* prefers young shoots for oviposition. It can be assumed that the preference of *L. chinensis* for selected shoots is due to the differing surface structure of onion leaves. As noticed, older leaves have a harder cuticle than younger ones. The latter might be difficult to penetrate for oviposition and mining of the larvae. This is confirmed by results of Wei *et al.* (2000) and Scheirs *et al.* (2003), who worked on other Agromyzidae species. Thus, peak abundances of *L. chinensis* in the first and second growth of spring onions can be explained by the higher numbers of young shoots in these crop stages, providing favourable conditions for egg deposition and mining of the larvae.

Abundances of *Philicoptus* sp. can be related to the cropping cycle and to the presence of certain weeds. Based on observations in the field and in feeding trials, the species preferred young crop plants of pechay (*Brassica chinensis* L.) and even more young plants and buds of the two weed species *Ageratum conyzoides* L. and *Crassocephalum crepidioides* (Benth.) S. Moore. It should be further examined, if the damage of *Philicoptus* sp. on the crop pechay might be reduced by growing *A. conyzoides* and *C. crepidioides* in the same field.

Philicoptus sp. is unable to fly (nonvolant). Since hoeing and weeding directly defines the conditions of the soil surface and plant density, it indirectly affects the spatial distribution of *Philicoptus* sp. The smoother soil surface and reduced plant density after weeding facilitated movement for the flightless weevil, which was also observed by Schotzko & Quisenberry

(1999) concerning the pea leaf weevil (*Sitona lineatus* (L.)). Thus the probability for emigration from the weeded area is higher after weeding which means a decrease in abundance. This decrease could not always be correlated with an increase in the more dense chayote stands, thus it does not seem that the beetle uses chayote as refuge.

The abundance peaks of *Hecalus* sp. in the vegetables are largely opponent to those in chayote. Therefore it can be assumed that *Hecalus* sp. uses chayote as refuge, but the underlying mechanisms remain unclear, since no preferences for any plant or plant organs could be observed. It was noticed by Kareiva (1983), Stanton (1983) and Power (1990, 1992) that homopteran insects are not more abundant in dense host plant stands, what is stated with the lower abundance of *Hecalus* sp. in the dense chayote compared to the simple structured, open vegetables. The abundances of *Hecalus* sp. did not show any correlation to planting, harvest, weeding or the presence or absence of weed species, which does not indicate any host preference but a general higher tendency for the consecutive changing vegetables.

Regarding the beneficials, *Homolictus* sp. was observed to be the main pollinator of crops and wild plants in the study area. The abundance of the bee in the rotating vegetables is resource oriented, with abundance peaks at the time of main flower supply. On the perennial chayote there are constantly few flowers present and also the abundance of *Homolictus* sp. was balanced. Chayote can be assumed to represent an important habitat for the maintenance of the pollinator population. Weeding as well as planting affected the occurrence of *Homolictus* sp. only indirectly by defining the flowering time of the emerging weeds and crops.

According to Kojima (1982), *R. f. flavobrunnea* is considered to be a common natural enemy of insect pests on Leyte. The abundance of *R. f. flavobrunnea* in the vegetable rotation is correlated with the infestation of the crops with potential prey, but not with planting, harvest or weeding of the plot.

The examples given provide an insight into the complex coherences of the single species with their environment, the biotic, abiotic and human influences. This part of the present study only considered two defined habitats with the main impact factors being planting, weeding and harvest, which affect by the presence or absence of crops, weeds and soil preparation.

Concerning selected insect species, it only was possible to generalize movement patterns regarding the significant different or not different abundances in the habitats and in the opposite arrival sides of the traps in each habitat. With respect to the population development of the species in relation to cropping patterns and agricultural practices applied no common patterns were found. This might be also due to the limited time frame of the study which did not consider possible further influences by e.g. the vegetation at field- and forest margin, different crop rotations and the macro and micro-climate within the area concerned.

For none of the species the same or similar pattern could be shown.

Insect populations respond to the availability of appropriate resources (e.g. Hoskin & Hutcheson 1986, Hutcheson 1991, White 1993, Stamps & Linit 1998), which, in the research area, are mainly affected by slash-and-burn agriculture. In the present study it was tried to identify the main impact factors affecting the insect community in original and modified habitats. It was found that plant diversity, vegetation structure and taxonomic composition as well as differences in turnover and productivity of the vegetation at habitats influence arthropod groups or species in different ways, which could not be generalised. Furthermore, it was concluded that none of the non-pest species considered in this study would be able to exist permanently in the agricultural area and that the pest species considered are limited to the cultivated land. Concerning movement patterns of selected insect species within the agricultural land, generalisation only was possible regarding significance of abundance variations at habitats and in the opposite arrival sides of the traps in each habitat. With respect to the population development of the species in relation to cropping patterns and agricultural practices, no common patterns were found.

The results contribute to the assessment of the effects of man-made habitat conversion on the arthropod fauna in tropical ecosystems. The identification and classification of habitats and their interactions might enhance the understanding of ecosystems in order to make aware the need to preserve and restore biodiversity. Finally, not only the agricultural sector should be considered in this process. Other domains of human live, e.g. family planning, education and income generation are interconnected with the agricultural sector and need to be considered in research and development activities.

8. Summary

Biodiversity and arthropod abundance patterns in the upland of Leyte, Philippines

In the humid tropics of SE-Asia the last primary forests are dwindling at an alarming rate. In many regions cultivated and degraded land outnumbers by far natural ecosystems. In the upland of Leyte island this is due to commercial and illegal logging activities and intensive slash-and-burn agriculture. The loss of the natural vegetation cover is accompanied by a decrease in diversity of fauna and flora, consequently also in ecosystem services and interactions, thus destabilizing the system and finally leading to degradation.

To further preserve and restore natural biodiversity landscapes dominated by man need to be included in an overall research strategy. So far only few studies focus on the biodiversity of cleared and converted land adjacent to natural areas in the tropics.

This study was conducted in a Philippine upland area and focused on interchanges of insects between the natural and the managed landscape. Two questions were approached. (1) Which structures and components of the cultural landscape are of significance for conserving arthropod biodiversity, and (2) are there species which originate from the natural forest and are able to become resident in the man-made systems?

In order to answer these questions insect- and plant surveys as well as the movement patterns of selected insect species were examined along a gradient from the natural forest through the agricultural land. So as to define the effects of habitat destruction on the arthropod community of the research area arthropod communities of different habitats between the natural and agricultural ecosystems with increasing distance to the forest, in relation to the vegetation were compared. Insect sampling was carried out using modified Malaise traps, whereby four habitats were considered: (a) forest interior, (b) forest margin, (c) vegetable fields and (d) chayote ((*Sechium edule* (Jacq.) Sw. (Cucurbitaceae); the only perennial vegetable of the area) fields. These traps allowed a separate catch for each of the two arrival sides, whereby the one was always opened to the forest and the other to the field. Trapping was set up for a total of 18 months in 2001 and 2002 at three sites with the four habitats each. Arthropod diversity, composition of the arthropod community and trophic guild composition at habitats were determined for each habitat and arrival side. Obtained results are presented and discussed with regard to first: arthropod diversity and community composition along the transect from natural through agricultural systems; second: abundance patterns of selected species in natural and agricultural systems and third: abundance patterns of selected species within the agricultural land.

It was found that plant diversity, vegetation structure and taxonomic composition as well as differences in the turnover of the vegetation at habitats (productivity of vegetation) influence arthropod groups and species in the study area in different ways which could not be generalised.

Further, the relationships of insects between the natural forest and the open agricultural land were considered. In order to identify species that occur in the forest as well as in the open country, first, insects at sites of the forest interior, the forest margin and the agricultural land, were recorded using modified Malaise traps. Then, movement patterns of selected species were determined based on their abundances at the different habitats and arrival sides. In addition it was tried to find out whether major pest species of the cultivated crops show any relationship to the adjacent natural forest, and whether species originating from the forest (non-pest species) are able to colonize open country. The results indicate that the habitat of the pest species considered is limited to the cultivated land and does not include the forest. None of the non-pest species recorded in this study would be able to exist permanently in the agricultural area. They all depend on a closed forest habitat and therefore will become extinct as the forest disappears with proceeding slash-and-burn agriculture. However, some but not all of the pest and forest species were regularly recorded from the forest margin.

Finally it was focused on relationships of insects between perennial and consecutive changing vegetable crops. Two kinds of habitats were distinguished: (i) frequently disturbed and rotational changing vegetables with simple architecture; (ii) rarely disturbed stands of chayote, with complex architecture. The impact of changing crop and weed species composition and the agricultural practices (soil preparation, planting, weeding, harvest) applied on the abundance of selected insect species and the question whether stands of chayote are used as refuge as long as conditions in the seasonal vegetables become unfavourable due to agroecosystem management applied were analysed. The insect species investigated include phytophagous specialists and generalists as well as beneficials (predators and pollinators). It only was possible to generalize movement patterns regarding significance of abundance variations at habitats and at opposite arrival sides of the traps in each habitat.

With respect to the population development of the species in relation to cropping patterns and agricultural practices applied no common patterns could be determined.

The results contribute to the assessment of the effects of man-made habitat conversion on the arthropod fauna in tropical ecosystems. The identification and classification of habitats and their interactions might enhance the understanding of ecosystems in order to make aware the need to preserve and restore biodiversity.

9. Zusammenfassung

Biodiversität und Abundanzmuster von Arthropoden im Hochland von Leyte, Philippinen

In den feuchten Tropen Süd-Ost Asiens nehmen die natürlichen Waldbestände weiterhin ab. Der Landschaftsanteil genutzter und degradierter Flächen liegt heute zumeist deutlich höher als derjenige naturbelassener Standorte. Im Hochland der Insel Leyte, Philippinen, wird der Verlust natürlicher Waldbestände vor allem durch kommerzielle und illegale Abholzung sowie intensive Brandrodung verursacht. Der Rückgang der natürlichen Vegetation wird begleitet von einer abnehmenden Vielfalt an Flora und Fauna und damit auch von Leistungen und Wechselbeziehungen innerhalb des Ökosystems. Dies führt zum Ungleichgewicht und letztendlich zur Zerstörung des betreffenden Ökosystems.

Um die natürliche Biodiversität so weit als möglich erhalten und wiederherstellen zu können, müssen sowohl die Ökosysteme der natürlichen als auch der genutzten und degradierten Flächen mit ihren Wechselbeziehungen erfasst werden. Bis heute hatten in den Tropen nur wenige Studien die Artenvielfalt degradierter und genutzter Flächen im Vergleich zu den angrenzenden, natürlichen Arealen zum Gegenstand.

Die vorliegende Studie wurde in einer Hochlandregion der Philippinen durchgeführt und konzentrierte sich auf ausgewählte Insekten und deren Wanderungsverhalten zwischen natürlichen (Regenwald) und landwirtschaftlich genutzten Flächen. Zwei Fragen standen hierbei im Vordergrund: (1) welche Strukturen und Komponenten der Kulturlandschaft sind für die Erhaltung der Arthropodendiversität von Bedeutung, und (2) gibt es Arten, welche im natürlichen System, dem Regenwald, beheimatet sind und sich in der neu entstandenen Kulturlandschaft ansiedeln können? Um diese Fragen zu beantworten, wurden Bestandsaufnahmen zum Vorkommen von Insekten- und Pflanzenarten entlang des Habitatgradienten Wald – Feld durchgeführt, sowie die Abundanzmuster ausgewählter Insektenarten erfasst.

Die Insekten wurden mit Hilfe modifizierter Malaise-Fallen in den vier Habitaten Wald, Waldrand, annuelle Gemüsekulturen, - und perennierende Chayote ((*Sechium edule* (Jacq.) Sw. (Cucurbitaceae), erfasst. Diese Malaise-Fallen erlauben den Rückschluss auf die Anflugrichtung der gefangenen Individuen, wobei zwischen „vom Feld in Richtung Wald“ und „vom Wald in Richtung Feld“ unterschieden wurde. Die Arthropodenfänge aus jedem Habitat, differenziert nach Anflugrichtung, wurden unter Berücksichtigung der jeweiligen Vegetation verglichen. Des weiteren wurden für jedes Habitat und jede Anflugrichtung die Diversität (nach Shannon) und Zusammensetzung der Arthropodenfänge, sowie die Verteilung der trophischen Ebenen bestimmt.

Die Ergebnisse wurden bezüglich des Einflusses der Vegetation auf Diversität und Zusammensetzung der Arthropodenfänge in den untersuchten Habitaten; der Abundanzmuster ausgewählter Arten zwischen Regenwald und Agrarökosystem, sowie der Abundanzmuster ausgewählter Arten innerhalb der landwirtschaftlichen Fläche dargestellt und diskutiert.

Als ursächlich für die Unterschiede in der Diversität und Zusammensetzung der Arthropodenfänge entlang des Habitatgradienten wurden der Artenreichtum, die Struktur und die taxonomische Zusammensetzung der Vegetation, aber auch Unterschiede im Wiederaufwuchs (Produktivität der Vegetation) in den Habitaten identifiziert. Die Auswirkungen dieser Faktoren auf die Abundanz der einzelnen Arthropodengruppen und Arten waren unterschiedlich und ließen sich nicht vereinheitlichen.

Des weiteren wurden die Abundanzmuster ausgewählter Insekten zwischen den drei Habitaten Wald, Waldrand und annuelle Gemüsekulturen berücksichtigt. Um Arten bestimmen zu können, welche in allen drei Habitaten vorkommen, wurden zunächst Fänge aus allen Habitaten verglichen und dann die Abundanzen der ausgewählten Arten getrennt nach Habitat und Anflugrichtung aufgezeichnet. Hierbei wurden neben den ausgewählten Nicht-Schädlingsarten (Indifferente; Bestäuber; Prädatoren) zusätzlich die wichtigsten Schadinsekten der Feldfrüchte berücksichtigt, um herauszufinden, ob diese eine Affinität zum natürlichen Ökosystem, dem Wald, zeigen. Zur Ergänzung der quantitativen Daten wurden regelmäßige Feldbeobachtungen der ausgewählten Arten durchgeführt.

Die ausgewählten Schädlingsarten konzentrierten sich überwiegend auf die landwirtschaftliche Fläche. Einige der ausgewählten Nicht-Schädlingsarten besuchten die landwirtschaftlichen Flächen regelmäßig, kehrten aber auch wieder in den Wald zurück. Die übrigen Nicht-Schädlingsarten konzentrierten sich auf den Wald und wurden nur sehr vereinzelt in den landwirtschaftlichen Habitaten erfasst. In Verbindung mit den Beobachtungen und der Auswertung existierender Literatur zeigten die Ergebnisse, dass keine der ausgewählten Nicht-Schädlingsarten allein in der Kulturlandschaft überleben kann. Alle benötigen zumindest zeitweise das Habitat Wald zur adäquaten Nahrungs- und Schutzsuche sowie Reproduktion. Fast alle der Schädlings- und Nicht-Schädlingsarten wurden regelmäßig am Waldrand erfasst. Diese Schnittstelle zwischen natürlichen und veränderten Habitaten fungiert als Grenze oder Transitzone für Insekten der angrenzenden Habitate oder beheimatet Arten, welche sich inzwischen auf diese Zone spezialisiert haben.

Schließlich wurden auch Abundanzmuster ausgewählter Insektenarten innerhalb der landwirtschaftlichen Flächen berücksichtigt. Unterschieden wurden die beiden Habitate Chayote, perennierend, selten durch menschliche Bearbeitung gestört, mit komplexer Struktur von Blättern und Stängeln, und regelmäßig wechselnde Gemüsekulturen, häufig bearbeitet, mit einfacher Wuchsstruktur. Um den Einfluss der wechselnden Zusammensetzung von Kulturpflanzen und Unkräutern sowie der unterschiedlichen landwirtschaftlichen Eingriffe (Bodenbearbeitung, Pflanzen, Jäten, Ernte) auf die ausgewählten Insektenarten untersuchen zu können, wurden die Populationsentwicklungen dieser Arten ebenfalls erfasst. Auch der Frage, ob Chayote - Pflanzungen als Rückzugsgebiet für Insekten dienen, solange deren eigentliches Habitat, die annuellen Gemüsekulturen, durch Bearbeitungsmaßnahmen gestört sind, wurde nachgegangen. Die ausgewählten Arten umfassten sowohl phytophage Spezialisten und Generalisten als auch Nützlinge (Prädatoren und Bestäuber). Die Ergebnisse zeigten, dass Abundanzmuster lediglich in Bezug auf signifikante Unterschiede der Abundanzen in den Habitaten und der beiden Einflugseiten der Fallen in den Habitaten Gemeinsamkeiten aufwiesen. Der Vergleich der Populationsentwicklung der ausgewählten Arten unter Einfluss der unterschiedlichen Kulturen und der landwirtschaftlichen Bearbeitung zeigte keinerlei Ähnlichkeiten.

Die vorliegenden Ergebnisse stellen einen Beitrag zur methodischen Erfassung der Auswirkung von anthropogen bedingten Habitatveränderungen auf die Arthropodenfauna in tropischen Landschaften dar. Die Identifikation und Klassifizierung von Habitaten mit der Beschreibung der zugehörigen Zusammenhänge sind die Grundlage für ein besseres Verständnis der Ökosysteme. Dies soll ein bewusstes Management von Kulturflächen fördern und letztendlich zur Erhaltung und Wiederherstellung der natürlichen Biodiversität beitragen.

10. References

Altieri, M. A. (1999): The ecological role of biodiversity in agroecosystems. Agriculture, Ecosystems & Environment 74, 19-31.

Altieri, M. A., Schmidt, L.L. (1986): The dynamics of colonizing arthropod communities at the interface of abandoned, organic and commercial apple orchards and adjacent woodland habitats. Agriculture, Ecosystems & Environment 16, 29-43.

Altieri, M. A., Schmidt, L.L. (1986): Population trends, distribution patterns and feeding preferences of flea beetles (*Phyllotreta cruciferae Goeze*) in collard-wild mustard mixtures: underlying mechanisms. Crop Protection 5, 170-175.

Altieri, M. A., Weid, J.-M. (2001): http://www.egfar.org/docs/english/4liners-docs/innopart/NRM/gfar0048.pdf

Angelsen, A., Kaimowitz, D. (2001): Agricultural Technologies and Tropical Deforestation CABI Interantional, NY.

Bach, C. E. (1980): Effects of plant density and diversity on the popualtion dynamics of a specalist herbivore, the stripped cucumber beetle, *Acalymma Vittata* (Fab). Ecology 61(6), 1515-1530.

Bach, C. E. (1984): Plant spatial pattern and herbivore population dynamics: plant factors affecting the movement patterns of a tropical cucurbit specialist (*Acalymma innubum*). Ecology 65, 175-190.

Basset, Y., Aberlenc, H.-P., Delevare, G. (1992): Abundance and stratification of foliage arthropods in a lowland rain forest of Cameroon. Ecological Entomology 17, 310-318.

Baumgärtner, J. (2000):
www.unep.org/bpsp/Agrobiodiversity/ agrobiodiversity%20thematic/biodivmitpests.pdf

Bawa, K. S., Seidler, R. (1998): Natural forest management and conservation of biodiversity in tropical forests. Conservation Biology 12, 46-61.

Beck, J., Schulze, C.H., Linsenmair, K.E., Fiedler, K. (2002): From forest to farmland: diversity of geometrid moth along two habitat gradients on Borneo. Journal of Tropical Ecology 18, 33-51.

Bedford, S. E., Usher, M.B. (1994): Distribution of arthropod species across the margins of farm woodlands. Agriculture, Ecosystems & Environment 48, 295-305.

Blanche, K. R. (2000): Diversity of insect-induced galls along a temperature-rainfall gradient in the tropical savannah region of the Northern territory, Australia. Austral Ecology 25, 311-318.

Boatman, N. (1994): Field Margins: Integrating agriculture and conservation British Crop Protection Council, Surrey, England.

Bolger, D. T., Suarez, A.V., Crooks, K.R., Morrison, S.A., Case, T.J. (2000): Arthropods in urban habitat fragments in southern California: area, age and edge effects. Ecological Applications 10, 1230-1248.

Borges, P. A. V., Brown, V.K. (2001): Phytophagous insects and web-building spiders in relation to pasture vegetation complexity. Ecography 24, 68-82.

Borrvall, C., Ebenman, B., Jonsson, T. (2000): Biodiversity lessens the risk of cascading extinction in model food webs. Ecology Letters 3, 131-136.

Bowden, J. D., G.J.W. (1977): The distribution of flying insects in and near a tall hedgerow. Journal of Applied Ecology 14, 343-354.

Braun-Blanquet, J. (1964): Pflanzensoziologie: Grundzüge der Vegetationskunde 3. Aufl., Springer Verlag, Berlin.

Bray, R. H., Kurtz, L.T. (1945): Determination of total, organic, and available form of phosphorus in soils. Soil Science 58, 39-45.

Brook, B. W., Sodhi, N.S., Ng, P.K.L. (2003): Catastrophic extinctions follow deforestation in Singapore. Nature 424, 420-423.

Brooks, T. M., Mittermeier, R.A., Mittermeier, C.G., da Fonseca, G.A.B. Rylands, A.B., Konstant, W.R., Flick, P., Pilgrim, J., Oldfield, S., Magin, G., Hilton-Taylor, C. (2002): Habitat loss and extinction in the hotspots of biodiversity. Conservation Biology 16, 909-923.

Brose, U. (2003): Bottom-up control of carabid beetle communities in early successional wetlands: mediated by vegetation structure or plant diversity? Oecologia 135, 407-413.

Burel, F., Baudry, J. (1995a): Species biodiversity in changing agricultural landscapes: A case study in the Pays´s Auge, France. Agriculture, Ecosystems and Environment 55, 193-200.

Burel, F., Baudry, J. (1995b). Farming landscapes and insects. In Ecology and integrated farming systems (ed D.M. Glen, Greaves, M.P. & Anderson, H.M.), pp. 203-220. John Wiley and Sons, NY.

Butler, L., Kondo, V., Barrows, E.M., Townsend, E.C. (1999): Effects of weather conditions and trap types on sampling for richness and abundance of forest macrolepidoptera. Environmental Entomology 28, 795-805.

Carvalho, K. S., Vasconcelos, H.L. (1999): Forest fragmentation in central Amazonia and its effects on litter dwelling ants. Biological Conservation 91, 151-157.

Chazdon, R. L. (2003): Tropical forest recovery: legacies of human impact and natural disturbances. Perspectives in Plant Ecology Evolution and Systematics 6, 51-71.

CIBA-GEIGY (1981): Manual für Feldversuche im Pflanzenschutz, Basel.

Costello, M. J., Daane, K.M. (1998): Influence of ground cover on spider populations in a table grape vineyard. Ecological Entomology 23, 33-40.

Dargantes, B. B. (1996): Socio-ecological case study on forestlands cultivation in Leyte, Philippines. Verlag W. & S. Koch, Stuttgart.

Davies, K. F., Margules, C.R. (1998): Effects of habitat fragmentation on carabid beetles: experimental evidence. Journal of Animal Ecology 67(3), 460-471.

Davis, A. J. (2000): Does reduced-impact logging help preserve biodiversity in tropical rainforests? A case study from Borneo using dung beetles (Coleoptera: Scarabaeoidea) as indicators. Environmental Entomology 29, 467-475.

Dennis, P., Fry, G.L.A. (1992): Field margins: can they enhance natural enemy population densities and general arthropod diversity on farmland? Agriculture, Ecosystems and Environment 40, 95-115.

Dennis, P., Young, M.R., Howard, C.L., Gordon, I.J. (1997): The response of epigeal beetles (Col.: Carabidae, Staphylinidae) to varied grazing regimes on upland Nardus stricta grasslands. Journal of Applied Ecology 34, 433-443.

Department of Environment and Natural resources (DENR) (1994): http://www.psdn.org.ph/cec/primer.htm

Didham, R. K., Ghazoul, J., Stork, N.E., Davis, A.J. (1996): Insects in fragmented forests: a functional approach. Trends in Ecology and Evolution 11(6), 255-260.

Didham, R. K., Hammond, P.M., Lawton, J.H., Eggleton, P., Stork, N.E. (1998): Beetle species responses to tropical forest fragmentation. Ecological Monograph 68 (3), 295-323.

Dudley, N., Jeanrenaud, J.P., Sullivan, F. (1998): The timber trade and global forest loss. Ambio 27, 248-250.

Duelli, P. (1990): Population movements of arthropods between natural and cultivated areas. Biological Conservation 54, 193-207.

Duelli, P., Obrist, M.K. (1998): In search of the best correlates for local organismal biodiversity in cultivated areas. Biodiversity and Conservation 7, 297-309.

Duelli, P., Obrist, M.K., Schmatz, D.R. (1999): Biodiversity evaluation in agricultural landscapes: above ground insects. Agriculture, Ecosystems and Environment 74, 33-64.

ecotech http://www.ecotech-bonn.de/

Ellingson, A. R. (1997):
www.colostate.edu/Depts/Entomology/courses/en507/papers_1997/ellingson.html

Elliot, N. C., Kieckefer, R.W., Lee, J., French, B.W. (1998): Influence of within-field and landscape factors on aphid predator populations in wheat. Landscape Ecology 14, 239-252.

Erwin, T. L. (1982): Tropical forests: their richness in coleoptera and other arthropod species. The Coleopterist Bulletin 36, 74-75.

FAO (2001): http://www.fao.org/

documents/show_cdr.asp?url_file=/DOCREP/006/AD642E/ad642e05.htm

Ferguson, A. W., Klukowski, Z., Walczak, B., Clark, S.J., Mugglestone, M.A., Perry, J.N., Williams, I.H. (2003): Spatial distribution of pest insects in oilseed rape: implications for integrated pest management. Agriculture, Ecosystems & Environment 95, 509-521.

Forman, R. T. T., Baudry, J. (1984): Hedgerows and hedgerow networks in landscape ecology. Environmental Management 8, 495-510.

Fretwell, S. D. (1977): The regulation of plant communities by food chains exploiting them. Perspectives in Biology and Medicine 20, 169-185.

Fretwell, S. D. (1987): Food chain dynamics: the central theory of ecology? Oikos 50, 291-301.

Fry, G. (1991). Conservation in agricultural ecosystems. In Scientific management of conservation (ed I.F. Spellerberg), pp. 415-443. Blackwell, Oxford.

Fu, C. B. (2003): Potential impacts of human-induced land cover change on East Asia monsoon. Global and Planetary Change 37, 219-229.

Geoanalytics (2003): http://www.geoanalytics.com

Giri, C., Defourny, P., Shrestha, S. (2003): Land cover characterization and mapping of continental Southeast Asia using multi-resolution satellite sensor data. International Journal of Remote Sensing 24, 4181-4196.

Goehring, D., Daily, G.C., Sekercioglu, C.H. (2002): Distribution of ground-dwelling arthropods in tropical countryside habitats. Journal of Insect Conservation 6, 83-91.

Grafton-Cardwell, E. E., Ouyang, Y., Bugg, R.L. (1999): Leguminous cover crops to enhance population development of *Euseius tularensis* (Acari: Phytoseiidae) in Citrus. Biological control 16, 73-80.

Gratton, C., Denno, R.F. (2003): Seasonal shift from bottom-up to top-down impact in phytophagous insect populations. Oecologia 134, 487-495.

Groetschel, A., Aquino, R.R., Buchholz, I., Eufracio-Mazo, T.G., Ibkendanz, A., Sales, N.A., Seven, N.A., Vicentuan, K.C. (2001): Natural resource management strategies on Leyte island, Philippines SLE, Berlin.

Groombridge, B. (1992): Global biodiversity: status of the earth's living resources Chapman & Hall, London.

Gustafson, E. J. (1998): Quantifying landscape spatial pattern: What is the state of the art? Ecosystems 1, 143-156.

Hamer, K. C., Hill, J.K. (2000): Scale-dependent effects of habitat disturbance on species richness in tropical forests. Conservation Biology 14, 1435-1440.

Hammer, Ø., Harper, D.A.T., Ryan, P.D. (2001): PAST: Paleontological Statistics Software Package for Education and Data Analysis. http://palaeo-electronica.org/2001_1/past/issue1_01.htm.

Hammond, P. (1994): Practical approaches to the estimation of the extend of biodiversity in speciose groups. Philosophical Transactions of the Royal Society of London, Series B 345, 119-136.

Hannunen, S. (2003): Trivial movements and redistribution of polyphagous insect herbivores in heterogeneous vegetation. Dissertation, Swedish University of agricultural Sciences, Uppsala.

Hanski, I. (1999): Metapopulation ecology. Oxford University Press, New York.

Hatley, C. L., MacMahon, J.A. (1980): Spider community organization: seasonal variation and the role of vegetation architecture. Environmental Entomology 9, 632-639.

Heck, K. L., Crowder, L.B. (1991). Habitat structure and predator-prey interactions in vegetated aquatic systems. In Habitat structure: the physical arrangement of objects in space (ed S.S. Bell, McCoy, E.D., Mushinsky, H.R.), pp. 281-299. Chapman & Hall, London.

Herren, H. (1998): Global environment and food security: Importance of arthropod diversity. Man and Development 20, 94-108.

Holloway, J. D. (1998). The impact of traditional and modern cultivation practice, including forestry, on Lepidopteran diversity in Malaysia and Indonesia. In Dynamics of tropical ecosystems (ed D.M. Newbery, Prins, H.H.T., Brown, N.D.), pp. 567-597. Blackwell Science Publishers, Oxford.

Holloway, J. D., Kirk-Spriggs, A.H., Khen, C.V. (1992): The response of some rainforest insect groups to logging and conversion to plantation. Philosophical Transactions of the Royal Society of London Series B, 335, 425-436.

Holloway, J. D., Stork, N.E. (1991). The dimensions of biodiversity: The use of invertebrates as indicators of human impact. In The biodiversity of microorganisms and invertebrates: its role in sustainable agriculture (ed D.E. Hawksworth). CAB International.

Horwitz, W. (1970): Official methods of analysis Association of official Analytical Chemists, Washington D.C.

Hoskin, G. P., Hutcheson, J.A. (1986): Hard beech (*Nothofagus truncata*) decline on the mamaku plateau, North Island. New Zealand Journal of Botany 24, 263-269.

Hummel, R. L., Walgenbach, J.F., Hoyt, G.D., Kennedy, G.G. (2002): Effects of production system on vegetable arthropods and their natural enemies. Agriculture, Ecosystems & Environment 93, 165-178.

Hutcheson, J. A. (1990): Characterization of terrestrial insect communities using quantified, malaise trapped coleoptera. Ecological Entomology 15, 143-151.

Hutcheson, J. A. (1991): Notes on the ecology of *Ectopsis ferrugalis* (Curculionidae). New Zealand Entomologist 14, 48-49.

Hutcheson, J. A., Jones, D. (1999): Spatial variability of insect communities in a homogenous system: Measuring biodiversity using Malaise trapped beetles in a *Pinus radiata* plantation in New Zealand. Forest Ecology & Management 118, 93-105.

Hutcheson, J. A., Kimberley, M.O. (1999): A pragmatic approach to characterizing insect communities in New Zealand: Malaise trapped beetles. New Zealand Journal of Ecology 23, 69-79.

Ingram, C. D., Buongiorno, J. (1996): Income and Diversity tradeoffs from management of mixed lowland Dipterocarps in Malaysia. Journal of Tropical Forest Science 9, 242-270.

Intachat, J., Holloway, J.D., Speight, M.R. (1997): The effects of different forest management practices on geometrid moth populations and their diversity in Peninsular Malaysia. Journal of Tropical Forest Science 9, 411-430.

Intachat, J., Holloway, J.D., Speight, M.R. (1999): The impact of logging on geometrid moth populations and their diversity in lowland forests on Peninsular Malaysia. Journal of Tropical Forest Science 11, 61-78.

Irwin, M. E., L.R. Nault, C. Godoy, G.E. Kampmeier (2000). Diversity and Movement patterns of leaf beetles (Coleoptera: Chrysomelidae) and Leafhoppers (Homoptera: Cicadellidae) in a heterogeneous tropical landscape. In Interchanges of Insects. Kluwer Academic Publishers. (ed B. Ekbom, Irwin, M.E., Roberts, Y.), pp. 141-168.

James, D. G., Stevens, M.M., O'Malley, K.J., Faulder, R.J. (1998): Ant foraging reduces the abundance of beneficial and incidental arthropods in citrus canopies. Biological Control 14, 121-126.

James, F. C., McCulloch, C.E. (1990): Multivariate analysis in ecology and systematics: panacea or pandora's box? Annual Review Ecological Systems 21, 129-166.

Jeanneret, P., Carmillot, P.-J. (1995): Movements of Tortricid moth (Lep. Tortricidae) between apple orchards and adjacent ecosystems. Agriculture, Ecosystems and Environment 55, 37-49.

Jonsen, I. D., Fahrig, L. (1997): Response of generalist and specialist insect herbivores to landscape spatial structure. Landscape Ecology 12, 187-195.

Kareiva, P. (1982): Experimental and mathematical analyses of herbivore movement: quantifying the influence of plant spacing and quality on foraging discrimination. Ecological Monographs 52, 261-282.

Kareiva, P. (1983). Influence of vegetation texture on herbivore populations: resource concentration and herbivore movement, Chapter 8. In Variable plants and herbivores in natural and managed systems (ed R. Denno, McClure, D.), pp. 259-289. Academic Press, NY.

Kato, M., Inoue, T., Hamid, A.A., Nagamitsu, T., Merdek, M.B., Nona, A.R., Itino, T., Yamane, S., Yumoto, T. (1995): Seasonality and vertical structure of leight-attracted insect communities in a Dipterocarp forest in Sarawak. Researches on Population Ecology 37, 59-79.

Kincaid, O. (2002): http://eces.org/articles/static/98290800079516.shtml

Kitching, R. L., Daiqin, L., Stork, N.E. (2001): Assessing biodiversity "sampling packages": How similar are arthropod assemblages in different tropical rainforests? Biodiversity and Conservation 10, 793-813.

Klein, A. M., Steffan-Dewenter, I., Buchori, D., Tscharntke, T. (2002b): Effects of land-use intensity in tropical agroforestry systems on coffee flower-visiting and trap nesting bees and wasps (Abstract). Conservation Biology 16, 1003-1014.

Klein, A. M., Steffan-Dewenter, I., Tscharntke, T. (2002a): Predator-prey ratios on cocoa along a land-use gradient in Indonesia. Biodiversity and Conservation 11, 683-693.

Kojima, J.-I. (1982): Nest architecture of three *Ropalidia* species (Hymenoptera: Vespidae) on Leyte island, the Philippines. Biotropica 14 (4), 272-280.

Köppen, W. (1931): Grundriss der Klimakunde W. de Gruyter & Col., Berlin & Leipzig.

Kranz, J., Schmutterer, H., Koch, W. (1977): Diseases, pests and weeds in tropical crops Paul Parey, Berlin, Hamburg.

Krebs, C. (1998): Ecological Methodology Benjamin / Cummings, Menlo Park Ca.

Laurance, W. F. (1999): Reflections on the tropical deforestation crisis. Biological Conservation 91, 109-117.

Laurance, W. F., Vasconcelos, H.L., Lovejoy, T.E. (2000): Forest loss and fragmentation in the Amazon: implications for wildlife conservation. Oryx 34(7), 39-45.

Lawton, H. J. (1983): Plant architecture and the diversity of phytophagous insects. Annual Reviews of Entomology 28, 23-39.

Lewis, T. (1969): The diversity of the insect fauna in a hedgerow and neighbouring fields. Journal of Applied Ecology 6, 453-458.

Leyte Government (2002): http://www.census.gov.ph/data/pressrelease/2002pr02122tx.html

Mader, H. J., Schell, C. & Kornacker, P. (1990): Linear barriers to arthropod movements in the landscape. Biological Conservation 54, 209-222.

Magurran, A. E. (1988): Ecological diversity and its measurement Cambridge University Press, Cambridge.

Majer, J. D., Recher, H.F., Ganesh, S. (2000): Diversity patterns of eucalypt canopy arthropods in eastern and western Australia. Ecological Entomology 25, 295-306.

Majer, J. D., Recher, H.F., Keals, N. (1999). Canopy arthropod faunas in fragmented landscapes. In Temperate Eucalypt Woodlands in Australia: Biology conservation, management and restoration (ed R.J. Hobbs, Yates, C.J.), pp. 235-247. Surrey Beatty & Sons, Chipping Norton.

Major, R. E., Christie, F.J., Gowing, G., Cassis, G., Reid, C.A.M. (2003): The effect of habitat configuration on arboreal insects in fragmented woodlands of south-eastern Australia. Biological Conservation 113, 35-48.

Malaise, R. (1937): A new insect trap. Entomologisk Tidskrift 58, 148-160.

Matlack, G. R. (1993): Micoenvironment variation within and among forest edge sites in the eastern United States. Biological Conservation 66, 185-194.

Maudsley, M., Seeley, B., Lewis, O. (2002): Spatial distribution patterns of predatory arthropods within an english hedgerow in early winter in relation to habitat variables. Agriculture, Ecosystems & Environment 89, 77-89.

Mesquita, R. C. G., Delamonica, P., Laurance, W.F. (1999): Effect of surrounding vegetation on edge-related tree mortality in Amazonian forest fragments. Biological Conservation 91, 129-134.

Moguel, P., Toledo, V.M. (1999): Biodiversity conservation in traditional coffee systems of Mexico. Conservation Biology 13, 11-21.

Moran, V. C., Southwood, T.R.E. (1982): The guild composition of arthropod communities in trees. Journal of Animal Ecology 51, 289-306.

Morisita, M. (1959): Measuring of the dispersion and analysis of distribution patterns. Memoires of the Faculty of Science, Kyushu University Series E. Biology, 215-235.

Morse, D. H. (1980): Behavioral mechanisms in ecology Harvard University Press, Cambridge.

Mueller-Dombois, D., Ellenberg, H. (1974): Aims and methods of vegetation ecology John Wiley and Sons, New York.

Müller (1979): http://www.cabi-publishing.org/Bookshop/Readingroom/0851993400/3400ch1.pdf

Murcia, C. (1995): Edge effects in fragmented forests: implications for conservation. Trends in Ecology and Evolution 10, 58-62.

Myers, N., Mittermeier, R.A., Mittermeier, C.G., Da Fonseca, G.A.B., Kent, J. (2000): Biodiversity hotspots for conservation priorities. Nature 403, 853-858.

Naeem, S. (2000): Reply to Wardle et al. Bulletin of the Ecological Society of America 81, 241-246.

Novotny, V., Basset, Y. (2000): Rare species in communities of tropical insect herbivores: pondering the mystery of singletons. Oikos 89, 564-572.

Novotny, V., Basset, Y., Miller, S.E., Kitching, R.L., Laidlaw, M., Drozd, P., Cizek, L. (2004): Local species richness of leaf-chewing insects feeding on woody plants from one hectare of a lowland rainforest. Conservation Biology 18, 227-237.

Novotny, V., Basset, Y., Miller,S., Allison, A. , Samuelson, G.A., Orsak, L. (1997): The diversity of tropical insect herbivores: An approach to collaborative international research in Papua New Guinea. In International Conference on Taxonomy and Biodiversity in East Asia, pp. 14, Soul, South Korea.

Odegaard, F. (2000): How many species of arthropods? Erwins estimate revised. Biol.-j.-Linn.-Soc. London: Academic Press 71, 583-597.

Oksanen, L. (1990a). Predation, herbivory and plant strategies along gradients of primary productivity. In Perspectives on plant competition, pp. 445-474. Academic Press, New York.

Oksanen, L. (1990b): Exploitation ecosystems in seasonal environments. Oikos 57, 14-24.

Oksanen, L., Fretwell, S.D., Aruda, J., Niemela, P. (1981): Explotation ecosystems in gradients of promary productivity. American Naturalist 118, 240-261.

Oliver, I., Beattie, A.J. (1993): A possible method for the rapid assessment of biodiversity. Conservation Biology 7, 562-568.

Oliver, I., Beattie, A.J. (1996): Designing a cost effective invertebrate survey: A test of methods for rapid assessment of biodiversity. Ecological Applications 6, 594-607.

Paoletti, M. G., Dunxiao, H., Marc, P., Ningxing,H., Wenliang, W., Chunru, H., Jiahai, H., Liewan, C. (1999): Arthropods as Bioindicators in Agroecosystems of Jiang Han Plain, Qianjiang City, Hubei China. Critical reviews in Plant Sciences 18 (3), 457-465.

Parker, M. (1984): Local food depletion and the foraging behaviour of a specialist grasshopper, *Hesperotettix viridis*. Ecology 65, 824-835.

Perfect, T. J. (1991). Biodiversity and tropical pest management, Chapter 12. In The Biodiversity of microorganisms and invertebrates - its role in sustainable agriculture (ed D.E. Hawksworth). CAB International.

Perfecto, I., Rice, R.A., Greenberg, R., Van der Voort, M.E. (1996): Shade coffee: a disappearing refuge for biodiversity. BioScience 46, 598-608.

Power, A. G. (1990). Cropping systems, insect movement, and the spread of insect-transmitted diseases in crops. In Research approaches in Agricultural Ecology (ed S. Gliessman), pp. 47-69. Springer, New York.

Power, A. G. (1992): Host plant dispersion, leafhopper movement and disease transmission. Ecological Entomology 17, 63-68.

Price, P. W. (1976): Colonization of crops by arthropods: Non-equilibrium communities in soybean fields. Environmental Entomology 5, 605-611.

Rabb, R. L. (1978): A sharp focus on insect populations and pest management from a wide area-view. Bulletin of the Entomological Society of America 24, 55-61.

Ramsay, G. W. (1986): The taxonomic impediment to conservation. The Weta 9, 60-62.

Rice, R. A., Greenberg R. (2000): Cacao cultivation and the conservation of biological diversity. Ambio 29, 167-173.

Ricketts, T. H., Daily, G., Ehrlich, P.R., Fay, J.P. (2001): Countryside biogeography of moths in a fragmented landscape: biodiversity in native and agricultural habitats. Conservation Biology 15, 378-388.

Risch, S. J. (1981): Insect herbivore abundance in tropical monocultures and polycultures: An experimental test of two hypotheses. Ecology 62, 1325-1340.

Risch, S. J., Andow, D., Altieri, M.A. (1983): Agroecosystem diversity and pest control: Data, tentative conclusions and new research directions. Environmental Entomology 12, 625-629.

Russel, E. P. (1989): Enemies hypothesis: A review of the effect of vegetational diversity on predatory insects and parasitoids. Environmental Entomology 18(4), 590-599.

Rypstra, A. L. (1983): The importance in food and space in limiting web-spider densities, a test using field enclosures. Oecologia 59, 312-316.

Sayer, J. A., Withmore, T.C. (1991): Tropical moist forests: destruction and species extinction. Biological Conservation 55, 199-213.

Scheirs, J., De Bruyn, L., Verhagen, R. (2003): Host nutritive quality and host plant choice in two grass miners: primary roles for primary compounds? Journal of Chemical Ecology 29, 1373-1389.

Schotzko, D. J., Quisenberry, S.S. (1999): Pea leaf weevil (Coleoptera: Curculionidae) spatial distribution in peas. Environmental Entomology 28, 477-484.

Schulze, C., Steffan-Dewenter, I., Tscharntke, T. (2004). Effects of land use on butterfly communities at the rainforest margin: a case study from Central Sulawesi. In Land use, nature conservation and the stability of rainforest margins in Southeast Asia (ed G. Gerold, Fremerey, M., Guhardja, E.), pp. 281-297. Springer-Verlag, Berlin, Heidelberg.

Schulze, C. H. (2000): Auswirkungen anthropogener Störungen auf die Diversität von Herbivoren - Analyse von Nachtfalterzönosen entlang von Habitatgradienten in Ost-Malaysia. Ph.D., University of Bayreuth.

Sheehan, W. (1986): Response by specialist and generalist natural enemies to agroecosystem diversification: A selective review. Environmental Entomology 15, 456-461.

Shelly, T. E., Villalobos, E. (2000): Buzzing bees (Hymenoptera: Apidae, Halictidae) on *Solanum* (Solanaceae): floral choice and handling time track pollen availability. Florida Entomologist 83, 180-187.

Siemann, E., Tilman, D., Haarstad, J., Ritchie, M. (1998): Experimental test of the dependence of arthropod diversity on plant diversity. The American Naturalist 152, 738-750.

Sittenfeld, A., Tamayo, G., Nielsen, V., Jimenez, A., Hurtado, P., Chinchilla, M., Guerrero, O., Mora, M.A., Rojas, M., Blanco, R., (1999): Costa Rican International Cooperative Diversity Group: Using insects and other arthropods in biodiversity prospecting. Pharmaceutical Biology 37 (suppl.), 55-68.

Smith, H. A., McSorely, R. (2000): Intercropping and pest management: a review of major concepts. American Entomologist 46, 154-161.

Stamps, W. T., Linit, M.J. (1998): Plant diversity and arthropod communities: Implications for temperate agroforestry. Agroforestry Systems 39, 73-89.

Stanton, M. L. (1983). Spatial patterns in the plant community and their effects upon insect search. In Herbivorous insects. Host seeking behaviour and mechanisms (ed S. Ahmad), pp. 125-157. Academic Press, New York.

Stary, P., Pike, K.S. (1999). Uses of beneficial insect diversity in Agroecosystem management. In Biodiversity in Agroecosystems (ed W.W. Collins, Qualset, C.O.), pp. 49-67. CRC, New York.

Stinner, R. E., Barfield, C.S., Stimac, J.L., Dohse, L. (1983): Dispersal and movement of insect pests. Annual Review of Entomology 28, 319-335.

Stork, N. E. (1987): Guild structure of arthropods from bornean rain forest trees. Ecological Entomology 12-, 69-80.

Tabarelli, M., Mantovani, W., Peres, C.A. (1999): Effects of habitat fragmentation on plant guild structure in the montane Atlantic forest of southeastern Brazil. Biological Conservation 91, 119-127.

Tilman, D., Kareiva, P. (1997): Spatial ecology. The role of space in population dynamics and interspecific interactions Princeton University Press, New Jersy.

Tole, L. (1998): Sources of deforestation in tropical developing countries. Environmental Management 22, 19-33.

Townes, H. (1962): Design for a malaise trap. Proceedings of the Entomological Society Washington 64, 253-262.

Townes, H. (1972): A light - weight malaise trap. Entomological News 83, 239-247.

Tscharntke, T., Kruess, A. (1999): Habitat fragmentation and biological control Cambridge University Press, Cambridge.

Tscharntke, T., Steffan-Dewenter, I., Kruess, A., Thies, C. (2002): Characteristics of insect populations on habitat fragments: A mini review. Ecological Research 17, 229-239.

Tscharntke, T., Steffan-Dewenter, I., Kruess, A., Thies, C. (2002): Contribution of small habitat fragments to conservation of insect communities of grassland-cropland landscapes. Ecological Applications 12, 354-363.

Turner, I. M. C., R.T. (1996): The conservation value od small, isolated fragments of lowland tropical rain forest. Trends in Ecology & Evolution 11, 330-333.

Turner, M. G., Gardner, R.H. & O'Neill, R.V. (2001): Landscape ecology in theory and process. Springer Verlag, New York.

Van Mele, P., van Lenteren, J.C. (2002): Survey of current crop management practices in a mixed-ricefield landscape, Mekong Delta, Vietnam - potential of habitat manipulation for improved control of citrus leafminer and citrus red mite. Agriculture, Ecosystems & Environment 88, 35-48.

Vasconcelos, H. L., Vilhena, J.M.S., Caliri, G.J.A. (2000): Responses of ants to selective logging of a central Amazonian forest. Journal of Applied Ecology 37, 508-514.

Watt, A. D., Stork, N.E., Eggleton, P., Srivastava, D., Bolton, B., Laren, T.B., Brendell, M.J.D., Bignell, D.E. (1997). Impact of forest loss and regeneration on insect abundance and diversity. In Forests and Insects (ed A.D. Watt, Stork, N.E., Hunter, M.D.), pp. 271-284. Chapman & Hall, London.

Wei, J. N., Zou, L.,Kuang, R.P., He, L.P. (2000): Influence of leaf tissue structure on host feeding selection by pea leaf miner *Liriomyza huidobrensis* (Diptera Agromyzidae). Zoological Studies 39, 295-300.

White, T. C. R. (1993): The inadequate environment. Nitrogen and the abundance of animals., Springer Verlag, New York.

Willott, S. J., Lim, D.C., Compton, S.G., Sutton, S.L. (2000): Effects of selective logging on the butterflies of a Bornean rainforest. Conservation Biology 14, 1055-1065.

Withmore, T. C., Sayer, J.A. (1992): Tropical deforestation and species extinction Chapman & Hall, London.

Wolda, H. (1981): Similarity indices, sample size and diversity. Oecologia 50, 296-302.

World bank (2000): http://www.popcom.gov.ph/sppr/statistics/table1.htm

Wright, J. S. (2002): Plant diversity in tropical forests: a review of mechanisms of species coexistence. Oecologia 130, 1-14.

Yang, L. H. (2000): Effects of body size and plant structure on the movement ability of a predaceous stinkbug, *Podisus maculiventris* (Heteroptera: Pentatomidae). Oecologia 125, 85-90.

Danksagung

Mein Dank gilt an erster Stelle Prof. Dr. Joachim Sauerborn für die Betreuung und Unterstützung der Arbeit von den ersten Ideen an. Dr. Priv. Doz. Dr. rer. nat. Konrad Martin für zahlreiche Gespräche, hilfreiche Kommentare und Anmerkungen und nicht zuletzt seine Besuche auf der Insel Leyte, Philippinen. Prof. Dr. Reinhard Böcker möchte ich für die Mitbetreuung danken.

Auf den Philippinen gilt mein Dank der Präsidentin der Leyte State University (LSU), Dr. P.P. Milan und ihren Mitarbeitern für die immerwährende Hilfe bei allen administrativen Angelegenheiten und die Integration in das soziale Umfeld der LSU. Den Mitarbeitern des Institute of Tropical Ecology, insbesondere Dr. M.J. Ceniza, für die Überlassung des Laborplatzes im Museum und die sehr freundliche Arbeitsatmosphäre.

Ganz besonders möchte ich mich bei Noel Morales für seine Freundschaft, Gesellschaft und tatkräftige Hilfe im Hochland von Leyte bedanken. Durch seine Mithilfe wurde der Kontakt zu den Bauern der Region, und damit erst die Durchführung der Feldversuche ermöglicht. Seinen Eltern und Geschwistern danke ich für wertvolle Einblicke in das Dorfleben, den Familienanschluss und die mir immer offen stehende Tür nach langen Feldtagen.

Auch an Gloria Bancale geht ein besonderer Dank für ihre Freundschaft und Unterstützung im Alltag und viele gemeinsame Erlebnisse.

Dr. V. Gapud (University Los Baños, Manila) und Dr. A. Riedl (Staatl. Museum für Naturkunde, Karlsruhe) bin ich für die Identifikation ausgewählter Insektenarten dankbar.

Nicht zuletzt geht mein Dank an meine Eltern, meinen Bruder und meine Großmutter, auf deren volle Unterstützung ich mich immer verlassen konnte.

Der Landesgraduiertenförderung Baden–Württemberg danke ich für die finanzielle Unterstützung der Auslandsaufenthalte.

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