CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

INSTITUTE OF TROPICS AND SUBTROPICS

Department: DASFPTS **Academic year: 2006/2007**

SETTING M.Sc. THESIS

For Mrs. Jitka Krausová BSc.

Course: Wildlife Management in Tropics and Subtropics

This thesis is required by the Head of Department as laid down in the rules of the Master studies at CZU.

Thesis Title:

Assessment of insect biological diversity of various land use systems in Peruvian Amazon

Code for compiling this M.Sc. diploma thesis

1. Introduction:
   Description of data collecting methods (catching of insects)
   Description of various land use systems in Peru
2. Aim of the thesis
   To monitor diversity of insects in various land use systems in Peru.
3. Methodology:
   Sampling
   Exemplar registration and evaluation of biological diversity
   Comparation of biodiversity in land use systems
4. Results and Discussion
   Evaluation of the results
   Discussion
5. Conclusions

Extent of the Thesis report: 80 pages

Bibliography:

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Thesis supervisor: Ing. Bohdan Lojka Ph. D.

Thesis consultant(s):

Date of M.Sc. thesis setting: October 2006

Date of handing over the thesis: May 2008

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Head of ITS CUA in Prague	**Prof. Ing. Bohumil Havrland, CSc.** **Director of ITS CUA in Prague**

Prague ……………………………

SEAL

Acknowledgement

I would like to express my sincere gratitude to Ing. Bohdan Lojka PhD. For his encouragement, guidance, and support were invaluable in my work.

I would also like to thank RNDr. Petr H. Verner form Czech University of Life Sciences for his support as my professional consultant and help with the entomological determination.

This work would not have been possible without the support of entomologists from the Charles University in Prague: Mgr. Petr Šípek, Mgr. Petr Janšta, Mgr. Jakub Straka, Mgr. Martin Fikáček, their aid with the insect determination. My thanks for help pertain to the Mgr. Petr Kment, specialists from the National Museum in Prague and to Mgr. Igor Malenovský (The Moravian Museum, Brno) as well.

The Academy of Sciences of the Czech Republic lends me the technical support by the laboratory room and technical equipment. My acknowledgement goes to them.

My hearty thank belongs to the organization Nadání Josefa, Marie a Zdeňky Hlávkových, who supported me financially on my journey to Peruvian Amazon.
Also the Expedition fund of the Klub Cestovatelů contributes financially to the realization of the research.

This research couldn't be realized without financial and scientific support of the project "Sustainable management of natural sources in Amazonia, Peru" (by CULS), realized in the frame of the official Czech development cooperation program.

Last but not least, I would like to thank my family and closest friends for always encouraging me, while my uneasy works in the terrain, and gave me the possibility of academic education and share happiness of achievement with me.

Statutory declaration

I hereby certify that I have elaborated my thesis independently, only with the expert guidance of my thesis tutor Ing. Bohdan Lojka PhD. and professional entomologists.

I further declare that all data and information I have used in my thesis are stated in references.

In Prague ………….

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Bc. Jitka Krausová

Abstract

Tropical rain forest form one of the most precious ecosystems and provide habitat for more than 65% described plant and animal species. This unique ecosystem is highly disturbed by human activities, which causes biodiversity losses. This study is focused on assessment of species diversity and richness in various land use systems around Pucallpa city (Peruvian Amazon). As the indicative group class *Insecta* was used. Our presumptions were that the species richness and diversity of secondary forest and agroforestry systems are higher than in monoculture cropping and degraded sites with weed vegetation. We supposed that in agroforestry systems there are fewer pests than in other agriculturally used localities. We also expected that ant species composition is helping to the pest control in the agroforestry systems. Insects were collected on six localities (secondary forest, two types of agroforestry systems, cassava monoculture and two degraded sites covered by weed vegetation) by using 24h-pitfall traps and sweeping net. The insect morphological species were determined and data evaluated according to standard methods and indexes.

Our hypotheses were fully supported excluding the biodiversity. The species richness was highest in the secondary forest and agroforestry, but the values for biodiversity were highest in the secondary forest and surprisingly on degraded sites. The lowest biodiversity was found in the agroforestry systems. The values were probably distorted by the dry season and higher occurrence of antropo-tolerant and pest species on degraded soils. Those species can survive the dry season without high losses. According to the index of similarity, the species composition of secondary forest is highly similar to the agroforestry systems. Based on this index we can declare that agroforestry systems can form insect species reservoir after forest disturbation and also help to the species conservation. This study summarizes the momentous role of ants in the tropical ecosystem and forms good scientific background for the further monitoring of ecological changes.

Key words

Abundance, agroforestry systems, deforestation, insect biodiversity, primary and secondary rain forest, shifting cultivation, species richness.

Abstrakt

Tropické deštné lesy tvoří jeden z nejvzácnějších ekosystémů a poskytují přirozené prostředí pro více než 65% popsaných rostlinných a živočišných druhů. Tento unikátní ekosystém je velmi narušován lidskou činností, což způsobuje pokles biodiverzity. Tato studie je zaměřena na sledování druhové diverzity na plochách s různým zemědělským využitím v okolí města Pucallpa (peruánská Amazonie). Jako indikační skupina byla vybrána třída hmyz (Insecta). Naším předpokladem bylo, že druhová pestrost a diverzita sekundárního deštného lesa a agrolesnických systémů je vyšší než v monokulturním porostu a na zaplevelených degradovaných plochách. Domnívali jsme se, že v agrolesnických systémech je méně škůdců než na ostatních zemědělsky využívaných lokalitách. Také jsme očekávali, že druhová složení mravenců v agrolesnických systémech pomáhá k regulaci škůdců.

Hmyz byl sbírán na šesti lokalitách (sekundární deštný les, dva typy agrolesnických systémů, monokultura – cassava a dvě plochy pokryté plevelnou vegetací) pomocí 24hod. zemních pastí a smýkací sítě. Hmyz byl zařazen do morfologicky odlišných druhů a data hodnocena na základě standardních metod a ukazatelů.Hypotézy byly plně potvrzeny kromě biodiverzity. Druhová pestrost byla nejvyšší v sekundárním deštném lese a agrolesnictví, ale hodnoty biodiverzity byly nejvyšší v sekundárním lese a překvapivě i na degradovaných plochách. Nejnižší hodnoty biodiverzity byly shledány v agrolesnických systémech. Hodnoty byly pravděpodobně zkresleny obdobím sucha a vyšším výskytem antropotolerantních druhů a škůdců. Tyto druhy mohou přežívat během období sucha bez významných ztrát.

Na základě ukazatele podobnosti je druhové složení sekundárního deštného lesa velice podobné druhům v agrolesnických systémech. Na základě tohoto ukazatele můžeme prohlásit, že agrolesnictví může tvořit druhový rezervoár po narušení původního lesa a dále napomoci k ochraně druhů.

Tato studie shrnuje druhovou diverzitu, významnou úlohu mravenců v tropickém ekosystému a tvoří dobrý vědecký základ pro následující sledování ekologických změn.

Klíčová slova

Početnost, agrolesnické systémy, odlesňování, biodiverzita hmyzu, původní a sekundární deštný les, "shifting cultivation", druhová pestrost.

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Acronyms and abbreviations

FAO	Food and Agriculture Organization of the United Nations
ICRAF	International Center for Research in Agroforestry
INRENARE	Institute fir the Management of Renewable Natural Resources
IUCN	International Union for Conservation of Nature and Natural Resources
Pers. comm.	Personal communication and/or correspondence
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
WWF	World Wildlife Fund

1. Introduction

The rain forests are unique world ecosystems that have a great ecological value. The largest one is tropical forest of south American Amazon Basin. It's a habitat for millions of plant and animal species. Only few percent of them were scientifically described (researchers say that only about 2 million of estimated 5-10 million insect species on Earth have been identified), for example 50 000 insect species are expected in natural rain forest.

The environment of Amazon Basin is under high population and ecological pressure. Increasing population density and activities of human are destroying the forest landscape and inflicts the loss of biological diversity. The devastation is caused also by farmers and their shifting cultivation. They slash and burn a part of the tropical forest, cultivate crops and after two years they leave degraded soil, infested by weeds, to cut down other part of the forest. The application of another type of agriculture could improve this situation. One of suitable systems is agroforestry, which could be more ecological and very well conserve natural sources. It is predicted that agroforestry systems can be sustainable and can work as the species reservoir. They also help to the soil and forest restoration, to control the troublesome weeds and are very important for the biodiversity conservation.

Monitoring and assessment of biological diversity plays very important role in the conservation of this ecosystem. This thesis focuses on assessment of biological diversity in the Peruvian Amazon. As an indicator of investigated group and its biodiversity assessment the class *Insecta* was chosen. Insect species richness and diversity has been evaluated in several different localities (secondary forest, two agroforestry types, monoculture cropping - cassava and two degraded sites covered by the weed vegetation). Further comparison of these entomologic data shows the biodiversity value of each assessed area and the role of agroforestry in the biodiversity conservation. In addition to the broad-spectrum investigation of insect biodiversity the consequential survey was done. This survey was aimed at ants *(Formicidae)* and its role in the agricultural ecosystem.

The thesis was realized around Pucallpa city (Ucayali region) in the Peruvian Amazon in cooperation with The National University of Ucayali in Pucallpa in the framework of the project "Sustainable management of natural sources in Amazonia, Peru" carried by the Institute of Tropics and Subtropics of The Czech University of Life Sciences and financed in the frame of the official Czech Development Cooperation Program. The main objective of the project is to improve production of small farmers through implementation of agroforestry practices.

2. Literature review

2.1. Biological diversity in tropical regions

Tropical ecosystems cover significant part of the Earth's surface and contain more than half of all terrestrial species (Myers, 1992). These ecosystems have played a unique role in the evolution of the planet's biodiversity.

2.1.1. Definition of biodiversity

Biodiversity has a great significance in modern studies of the nature and its richness. It is important especially in wide and complex view on the nature and ecosystem. Definition of biological diversity has been developed mainly during last decades and it is still changing according to new studies and information. Takacs (1996) define it generally as the "full variety of life on Earth".

It is very difficult to define the biological diversity briefly and properly because of its width and pithiness. The World Fund of Nature Protection presents biodiversity as the richness of live on the Earth. Kim and Martz (2001) define biodiversity as the variety and variation of all species of plants, animals, fungi, and microbes, including their genetics, their ecological roles, and their interrelationships in biological communities throughout the world ecosystems. More closely and specifically Bell *(pers. comm.)* declare that *biodiversity* is the study of processes that create and maintain variation. It is concerned with the variety of individuals within populations, the diversity of species within communities, and the range of ecological roles within ecosystems.

Basically it could be perceived as a richness of the world ecosystems at all its levels including richness at the level of genes as was defined by the IUCN, UNEP and WWF in 1991: "The variety of life in all its forms, levels and combinations. It includes ecosystem diversity, species diversity, and genetic diversity." Genetic diversity has its high importance for the species conservation, because big percentage of species endangerment or extinction is caused by the loss of genetic diversity.

The biodiversity can be assessed at following different levels: Genetic, Species and Ecosystem diversity.

1. Genetic diversity is a rich genes diversity of the species. Populations of the same species or genetically different individuals of one population belong to this group. Losses of species diversity are (in small populations) often caused by losses of genetic diversity.
2. Species diversity means species richness and numerousness on the selected area. It can be divided in following three groups.

a) Species richness - number of species on the selected area ("species per country")

b) Taxonomic diversity - describes varieties of species and prefers taxonomic hierarchy. (e.g.: locality with occurrence of 3 insect species has lower taxonomic diversity than locality with occurrence of 1 insect species and 2 mammal species.)

c) Functional diversity - assesses status of individual species in the view of its function of the ecosystem (hierarchy, food chain, etc.) and determines the keystone species, who are indispensable for the existence of other species. Functional diversity is given by the number of relations, interactions, processes and strategies of organisms in the ecosystems.

3. The ecosystem diversity is a complex evaluation of diversity according to societies and ecosystem parameters.

This thesis is focused mainly on the species diversity, because it's an excellent richness indicator of monitored areas.

2.1.2. Concept of Tropical biodiversity

The biodiversity is not simply a measure of world's species; rather, it also encompasses genetic variability within and between populations, species` evolutionary histories, and other measures of the diversity of life. Biodiversity patterns vary between regions. Tropics, particularly tropical forests, are expansive biodiversity reservoirs (Stevens, 1989). Tropical ecosystems cover a large part of the earth's surface and contain more than half of all terrestrial species (Myers, 1992). Suitable environmental conditions allow the occurrence of a big amount of plant and animal species. High diversity in the tropics is generally attributed to high productivity, low environmental variance (e.g., seasonality), persistent predation and competition, lower historical climatic change impacts, and differential speciation and extinction rates. Recognizing that these attributes tend to support high diversity in the tropics, it is important to note that there are significant intra-tropical diversity patterns and that lower-diversity regions can also be found in the tropics (Schroth, Da Fonecsa, 2004). These regions are very often situated around tropical cities. Monitoring of the biodiversity gives a complex overview of the selected locality (ecosystem) and occupies one of top positions in disciplines of ecology, zoology and botany regarding to its importance. Assessment of the biodiversity is the most important first step to the species conservation, because describes both species and their natural habitat and ecological interactions.

2.1.3. Loss of biological diversity by forest destruction

Tropical rainforests are highly destructed by activities of human. The rapid destruction of tropical primary forests is one of driving factors for the global loss of biodiversity (Sala et al. 2000).

Indigenous people (pickers, hunters) are not changing the forest ecosystem significantly, but even the simple agriculture cause extensive and considerable changes of the nutritional reserves, biodiversity and society structure. Remaining areas of tropical rainforest are threatened by the expansion of agricultural land-use resulting from human population growth (Ocana et al. 1992; Pimentel et al. 1992). In particular secondary forests that constitute the increasing part of tropical landscapes (Brown and Lugo, 1990), high potential for maintaining at least a certain part of tropical diversity appears (Lawton et al. 1998; Intachat et al. 1999; Raman 2001). This potential may be of particular importance in Southeast Asian and South American rainforest regions, where secondary forests arise as a result of shifting cultivation (Brown and Lugo 1990).

Many species (not only endemic) are specialists, depending on particular abiotic and biotic habitat characteristics, such as low light-intensity, special food plants etc. Therefore they respond very sensitively to environmental perturbations. Habitat characteristics, such as vegetation and plant community structure, change during succession, thereby influence insect communities (Southwood et al., 1979).

2.2. Amazon basin

2.2.1. Location, history and climate

The Amazon Basin is the largest drainage basin on the planet. It is situated completely within tropics (*Figure 1*), between 5° N and 17° S, 79°W, 46° and occupies more than one third of the South American continent (Barthem et al., 2004). It covers an area in of more than 6 million km^2, which is divided between countries of Brazil (66%), Peru (15%), Bolivia (12%), Colombia (5%), Ecuador (2%), and a small section of Venezuela (< 1%) (Hoorn, 1995). Minimally 5.5 millions km^2 are occupied by the rain forest (for example 60% of Peru forms the rain forest.)

Figure 1: Geographical location of the Amazon basin.

The basin consists of east-west trending lowland surrounded by highlands. On the north and south these highlands are formed by Guyana and Brazilian Precambrian shields respectively. To the west, the Andean cordillera stands as a formidable barrier isolating the Amazon basin from the Pacific basin. The Andes were formed by a long series of weathering events extending back to the Triassic Period, about 200 million years ago. However the river system we see today in the Amazon is estimated to have been formed approximately 24 million years ago in the Miocene Epoch (Hoorn, 1995), when the final gap in Andes closed and the Amazon basin was permanently cut off from the Pacific.

During following millions years fauna and flora could be specifically developed into plenty of plant and animal species and this way have formed a unique ecosystem with very high biodiversity. According to Erwin (1988) during the intervening 20 million years, the Amazon has been a site of unparalleled biological productivity and diversification. Favorable conditions of moisture and warm punctuated by varied and dramatic phases of large-scale disturbance have produced a landscape containing as many as one third of Earth's plant and animal species, and much more when projected number of insect species are considered.

Forests of Amazon basin have a great importance in modern biological studies. A big number of non described plant and animal species is estimated. This high biological diversity is allowed by the convenient environmental and climatic conditions.

The central area of the Amazon is generally hot and humid, seasonally this doesn't change dramatically. The warmest months are August through October/November; coldest months are January, February, March, and April. According to Sioli (1975) the temperatures are not enormous, annual mean temperature vary from 24 to 26°C. In the mountainous areas the annual average is below 24°C, while along the Lower and Middle Amazon the mean temperature exceeds 26°C. Relative humidity is high year-round. It averages 75.6% in September, and 86.7 % in April. This quite stable climate is very favorable for many species and creates good conditions for their reproduction and survival. Also water regime is very important for the biodiversity preservation. Water regime is driven by rains and big rivers (Amazon, Ucayali, Purus, Negro, etc.).

The rains and the precipitation vary according to the location and season. In the west rains are relatively evenly distributed (Simpson & Haffer 1978, Salati 1985). Mean annual rainfall discounts variations throughout the Amazon Basin, generally oscillating between 1 000 mm and 3 600 mm, but exceeding 8 000 mm in the Andean foothill region (Day & Davies 1986, Goulding et al. 2003). According to Junk (1997) total rainfall averages 2100 mm a year. Local rainfall distribution varies strongly and would of course have a large impact on plants´ and animals´ life.

Precipitation is periodic. As more than half of the total precipitation is recycled by evapo-transpiration, the Amazon rainforests maintain the rainfall patterns and the hydrological cycles in the region (Salati et al. 1978). The rainy season lasts from December to April, and dry season from June to October. A shorter rainy season also occurs, for a period of days or few weeks only, between October and December. This short dry season has ecological impact on herbaceous plant growth and on the breeding behavior of animals.

2.3. Amazon rainforest

The major area of the Amazon basin is covered by the tropical rain forest. It's a unique forest ecosystem, dependent on good water and temperature conditions. Tropical rain forest is generally described as a woody biome with constant humid and hot climate.

2.3.1. Definition and concept

Rainforests are defined ecologically as closed (>70 percent projective foliage cover) broad-leaved forest vegetation with a continuous rainforest tree canopy of variable height, and with a characteristic diversity of species and life forms. Rainforest canopy species are defined as shade-tolerant tree species that are able to establish below an undisturbed canopy, or in small canopy gaps resulting from locally recurring minor disturbances, such as isolated wind throw or lightning strike, that are part of the rainforest ecosystem. These species are not dependent on the fire for their regeneration (Gell and Mercer, 1992).

Tropical rain forests represent zonobiome in the areas of tropical per humid and humid climate. There are synonyms as: tropical primeval forest, jungle etc. The attribute *evergreen* is used very often. Except geographical and bio-geographical divergences the rainforest can be divided into several pedobiomes and orobiomes (Jeník, 1995):

- *lowland tropical rain forest (zonobiome)*
- *mountain tropical rain forest (orobiome, altitude app. 1000 m)*
- *cloud tropical forest (altitude form 2000m up to 3000m)*
- *alluvial tropical rain forest (pedo-biome of fluvial plains of big rivers)*
- *tropical paludal forest (pedo-biome)*

These zonal biomes (zonobiomes) determine climatic and soil conditions important for the production.

2.3.2. Production

The primary production – tropical rain forest represents a biome with a maximal intensive nutrient circulation and diversity of interactions among its components. Growth of individual forest components is exceptionally fast particularly after disruption of current structure. Annual growth of the wood matter can be up to several meters. Production of this biome is characterized by high input of solar energy, year-round high temperature, optimal water sources, maximal diversified sources of genetic information and low soil nutrient reserves. Nutritional reservoir is conditioned by the biological fixation. Soils of the tropical rain forests are very predisposed to degradation after deforestation. Nutrients are leached to deep soil layers by frequent rains and its content is getting lower. Fallen organic matter is, in good conditions, very rapidly decomposed by the consumments, decomposer and reducents. Recently acquired nutrients are rapidly used by plants for the biomass production. Amount of the current biomass and the biomass production is very high. Accumulation of the biomass reach up to 1500 tons of the green weight per ha. The part of above-ground biomass is dominant (75 – 85%). Gross primary production reach up to several tens of tons (20 – 50 tons/ha/year). Secondary production (production of consumers of first and second level) is very low. Higher levels of the food chains are distinguished by the high occurrence of omnivores (caused by low occurrence of monotypic food sources). Species with low food demands (for example insects and small vertebrates) are represented by really high diversity and also often by limited area of occurrence.

2.3.3. Natural (primary) rainforest

Trees are dominant living forms of the rainforest. The structure of vegetation is complicated, has up to 5 levels (*Figure 2*) and species diversity is incomparable with other world terrestrial ecosystems.

1st – herb layer
2nd – immature layer
3rd – understory layer
4th – canopy layer
5th – emergent layer

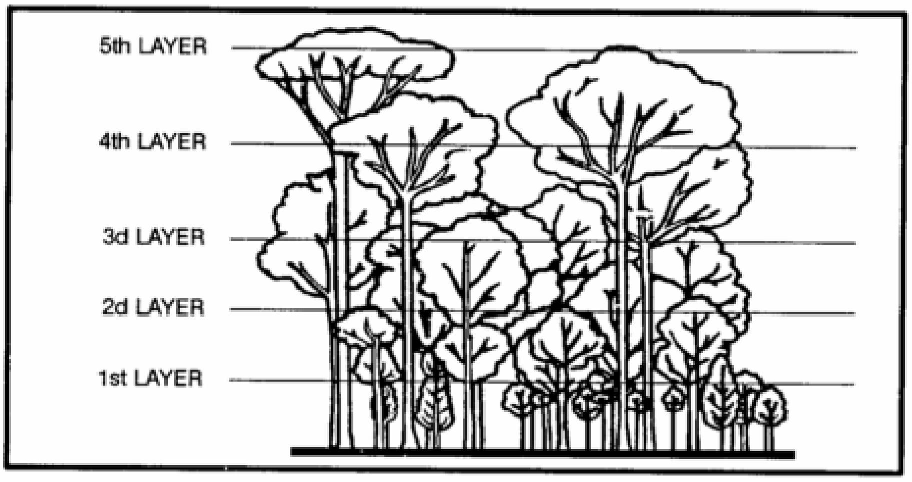

Figure 2: Illustration of the rainforest layers.
(References online, [1])

Herb layer	-	The forest floor may lie more than 60 feet (18 meters) below the canopy. This layer contains mostly seedlings, herbs, and ferns. Vegetation is sparse due to the reduced amount of sunlight. Temperatures at this level may be considerably cooler than in the canopy.
Immature Layer	-	Shrub layer is the small layer just above the floor. This layer contains many large-leaved plants and small trees that are able to survive with poor sunlight.
Understory layer	-	below the canopy is the understory layer, which contains small trees about 30-60 feet (9-18 meters) in height. Some of these trees will eventually form part of the canopy, while others will remain in the understory. Lianas, orchids, and bromeliads also form a part of this layer.
Canopy layer	-	second layer, the canopy, is formed by trees that grow between 60 and 150 feet tall (18-46 meters). The flat crowns (tops) of these trees form a dense habitat that sustains most of the plant and animal life found in tropical rainforests. Many animals live their entire lives in the canopy where much of the food they need is produced. The canopy layer also serves as a sunshade for the rainforest below, absorbing a majority of the sunlight. Only about two to five percent of the sunlight penetrates the canopy and reaches the forest floor.
Emergent layer	-	The uppermost layer of the tropical rainforest, known as the *emergent* layer, consists of giant trees from 150 to 250 feet tall (46-76 meters) that emerge from the canopy to form an extra umbrella-like layer. Sloths, monkeys, and a variety of bird species occupy this layer.

Tropical vegetation of the primary rainforests is very dense (*Figure 3*), for example, in the area of 1ha up to several hundreds tree species (app 400 species) can occur. Dominant individuals of the tree component can grow to the height of 30 – 40 m and their longevity is 200 – 300 years. Root system has varied types of adaptations for increasing mechanical tree stability in the humid soil. Leave change frequency is approximately once per fourteen months.

Figure 3: Primary rain forest (References online, [2]).

Other vegetation levels are formed by woody and herbaceous lianas, epiphytes, parasites and hemi-parasites, green and under ground saprophytes. The ground layer is poor in the biomass productivity. Also the activity of photosynthesis is extremely low because of sunlight deficiency. Most of photosynthesis activities are concentrated to upper parts of the forest vegetation. Lower layers occur often in the opening, which represents an important phase of its succession.

Also the animal biodiversity is extremely high; estimated amount is 68.8 % of all terrestrial animal species. Rainforests are also called as "biodiversity hot spots". Good and stable climatic conditions enable the high vegetation growth and development of the environment which provides lots of habitats for insects. In this very various environment lots of herbivore, predator and also parasitical insect species are developed. Each of them has a different position in the food and ecological chain and that way is stabilizing the natural ecological balance. Insects are by far the most diverse and abundant animals in tropical forests. Studies have found that a single square mile of rainforest often houses more than 50,000 insect species (References online, [3]). The high biodiversity can be found in the tropical ant species. Ants can form up to 80% of the species amount. This number depends on the primary rainforest condition. Different numbers can be found by studying secondary rainforest biodiversity.

2.3.4. Secondary rainforest

The term *primary forest* is commonly perceived as the "climax forest type" for a given region and environment, which is thought to be relatively stable. The term *secondary forest* then relates to succession of forests that have been developed after clearing of the original forest, and secondary succession is complete when they develop into climax communities or primary forests again (Clements, 1916). Secondary forests were covering 165 million ha in 1990 in Latin America (FAO, 1996).

More detailed definition of the secondary rainforest was published by Chokkalingam and De Jong (2001): Secondary forests are forests regenerating largely through natural processes after significant human and/or natural disturbance of the original forest vegetation at a single point in time or over an extended period, and displaying a major difference in forest structure and/or canopy species composition with respect to nearby primary forests on similar sites.

The main key characteristics of this definition are a) the original forest vegetation was significantly disturbed. b) The disturbance to the original forest vegetation could have been natural and/or human-initiated. c) The disturbance may have occurred all at once or progressively. d) The forest is a regenerating or redeveloping one. e) Most of the regeneration is spontaneous. f) The regenerating forest has significantly-different forest structure or canopy species composition or both, as compared to nearby primary forests on similar sites (Chokkalingam, De Jong, 2001).

The restoration of the tropical vegetation after disturbance takes tens of years to return to the climax frame. During this time its canopy changes and form one-layer canopy vegetation to the multi-layer canopy vegetation (*Figure 4. and 5.*).

Tropical forest is disturbed by the fire, insect infestation, windstorms, etc., but mainly is disturbed by the human activities (clearing, agriculture, timber logging). Wood logging industry is trying to cover the demand of exotic woods. The peasants increase the devastation too, by the forest burning for their traditional agriculture. Tropical peasants are slashing and burning wide areas of the forest to gain the space for their agricultural plantation. The soil on the deforested area is loosing its fertility during one or two years of plantation and peasants are leaving it to slash-and-burn other part of the forest.

Figure 4: Young secondary forest
(References online, [2])

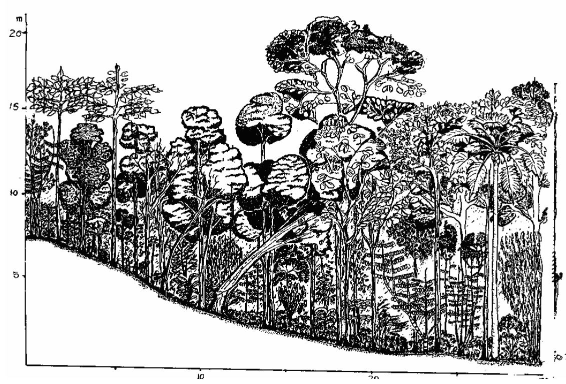

Figure 5: Old secondary forest
(References online, [2])

The soils under tropical rain forest don't have large nutrient reserves and are very susceptible to the soil erosion and nutrient loss after disturbances. This vegetation and nutrients loss is accompanied by a high loss of the biodiversity. Succession of the area disturbed by the human takes lots of years and stabilization of the ecosystem is very slow and origins a new vegetation – the secondary rain forest. Secondary forest is shorter, more open with one or two canopy layers *(Figure 6.)* and lower species diversity. Not only loss of habitats but also change of climatic conditions is causing lower biodiversity. The secondary rainforest can house approximately 23 thousand and more of insect species according to the forest development. Of this amount up to 58% could be represented by ant species. Especially soil ants are helping to the secondary forest development. According to Brian (1978) ants are increasing the soil aeration by the underground nest construction and also improve the drainage system of the soil. But not only soil ants occurs here, there are also leaf-cutter a harvester ants, predators and melivors living in the forest. The structure of interactions among species with the specific relations to the environment is also highly different from the primary rainforest.

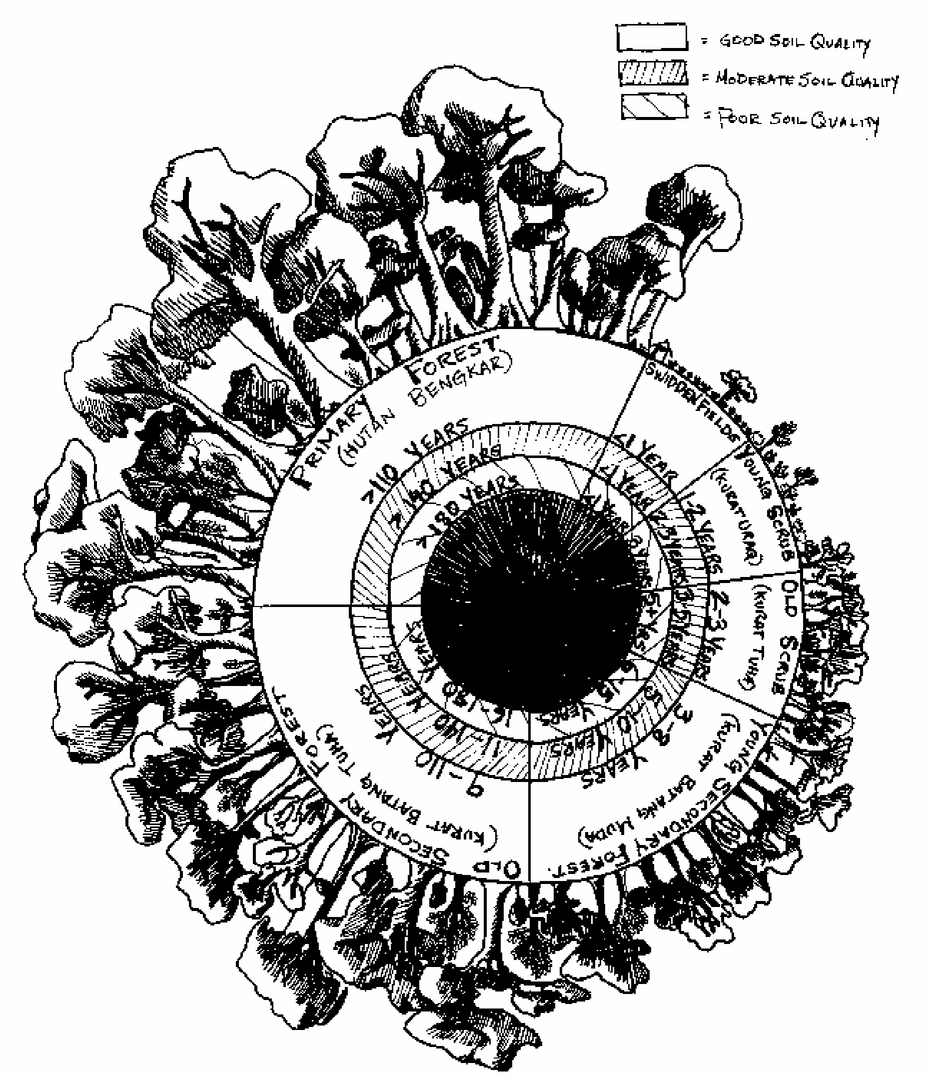

Figure 6: Graphic overview of the forest development.

(References online, [2])

The succession of the primary rainforest vegetation takes more than hundred years. The indigenous insect species are reverting to the rainforests according to the vegetation change and this recurrence takes from 50 to 100 years too.

2.4. Land-use systems in Peruvian Amazon and its impact on the biodiversity

2.4.1. Traditional agriculture in Amazon and deforestation

The most widespread land use system in the Amazon Basin is “shifting cultivation”. Shifting cultivation is an agricultural system which temporary clearings in are cropped for fewer years than they are allowed to remain fallow (Sanchez, 1973). It is the oldest system of agroforestry.

Estimates suggest that shifting cultivation activities destroy 50,000 km^2 and degrade further 10 million km^2 of tropical rainforest a year (Park 1992). Smallholders or primitive farmers and herdsmen, who are producing food for their subsistence and the rest are selling in the local market, are frequent. Shifting cultivation is the most widespread type of tropical soil management technique.

Indigenous farmers use the method of migratory agriculture with a following leaving of cultivated areas and stumping of new plots, where maize, rice, etc are usually cultivated as a monoculture. New plots are loosing its soil fertility after one or three years of plantation and all process repeats. Peasants come back usually after several tens of years. In the dense populated areas is the pressure and food demand highest. Shifting cultivators are coming back earlier and the secondary vegetation (forest) that doesn’t have enough time to renew. The vegetation is degraded and soil is loosing its fertility more rapidly. After several years only green savanna vegetation composed mainly of very resistant weeds remains. Moran (1987) and UNESCO/UNEP/FAO (1978) declares that the term “pioneer swidden” is also used to refer to the shifting practices of peasant migrants who move into the forest, swidden, and later abandon a degraded field and/or establish permanent field cultivation (*Figure no.7.*). Having a little prior knowledge of swidden techniques, these peasants often devote all their agricultural efforts to making a swidden, but in most instances they do not have enough knowledge of the forest ecosystem to develop a shifting cultivation system that can be sustainable. This is especially the case of most smallholders in Amazon Basin. There are high deforestation rates caused by the logging companies and by the local farmers too. Much of the deforestation in the last 50 years has occurred. The great deforestation is caused mainly by the shifting cultivation under the big population pressure. High population density has bigger food demand, fallow periods are shorter and the soil degrades.

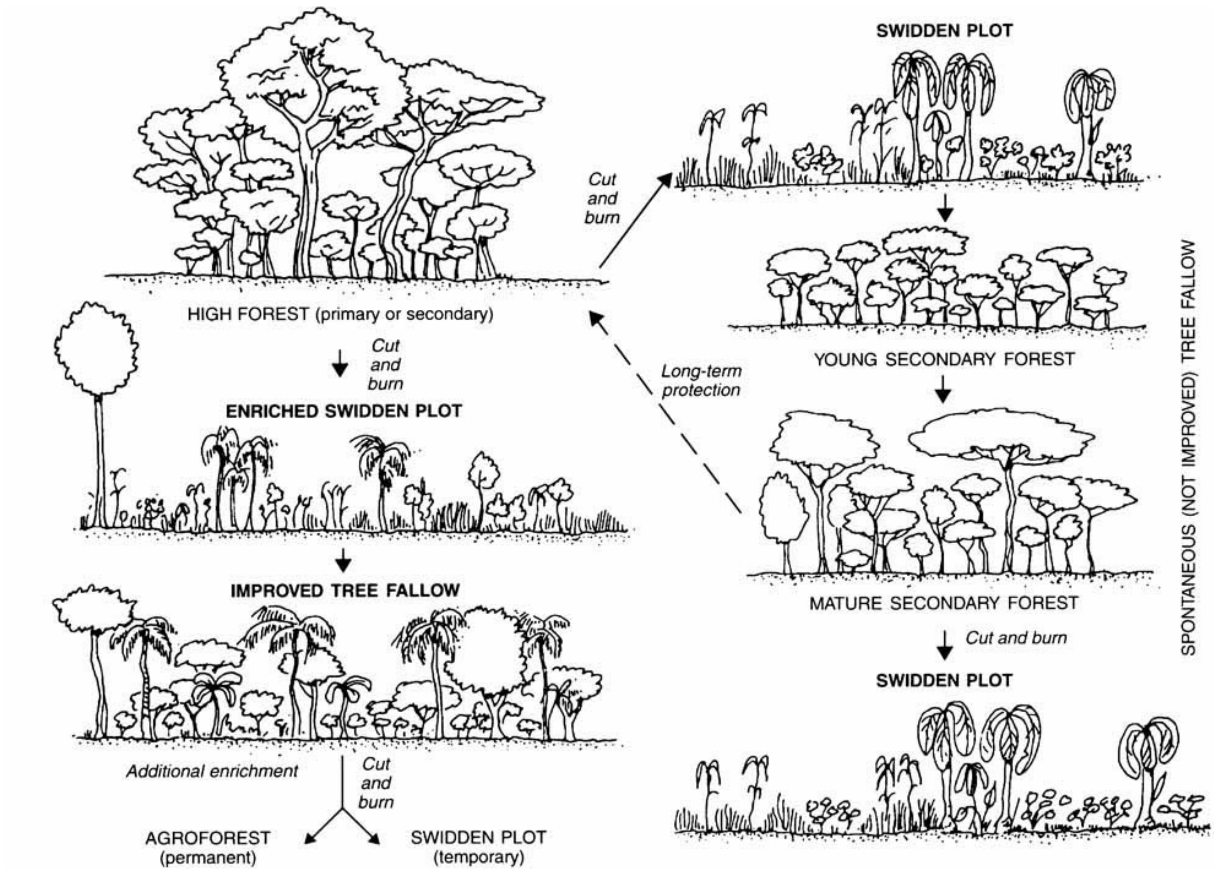

Figure 7: Pattern of the swidden plot origin from the rainforest. (References online, [4])

Between 1990 and 2005, Peru lost 2.0% of its forest cover, or around 1`414`000 hectares *(References online, [5])*. In these numbers is also included the amount of the deforestation by the shifting cultivators. After deforestation, the land is infested by weeds in few years.

2.4.1.1. *Imperata* problem

On a hardly degrades soils, caused by Amazonian shifting cultivators, mainly weeds are growing. The most common and problematic weed grass species is *Imperata spp. (Figure 8.). Imperata* is considered as the worst weed of south eastern Asia, where it already covers as much as 25 million of hectares, moist savanna of the West Africa and now it starts to be the same threat also in South America particularly in Amazon Basin (Garrity *et al.* 1997). *Imperata* is distributed in South America, Central America, Mexico, West Indies and United States. *Imperata* is an erect, tufted perennial grass with rhizomes, to 100 cm tall. It is abundant and weedy in South American tropic lowlands and it likes habitats with low altitudes, sandy and humid soils. It's a weed of waste places and perennial crops. In the Amazon basin it is growing on open deforested and degraded area.

Figure 8: Imperata vegetation in Antonio Raimondi/Peru. (Foto Jakub Vícha, 2007)

Imperata (also called *Cashausha*) is a big problem for local farmers. *Imperata* is shade intolerant, although little is known about relative roles in the competition for light, water and nutrients in suppressing its growth (MacDicken et al., 1997). When the forest is cleared, area opened and soil degraded, *Imperata* is infesting these places widely (for example areas degraded by the shifting cultivation) and green savanna occurs instead.

This weed is very fast growing, rapidly and aggressively progressing and resistant to the frequent fires. This weed doesn't have other utilization for example as the fodder for animals. The cattle are not ingesting it well (rarely young weed outgrowths). As a traditional method of the *Imperata* clearing out of the fields and pastures, the fire is used frequently. The burning of the biomass provides fertile ash, which is helping to the regeneration of the weed vegetation and to grow even more aggressively. In a short time after burning the new plants start to flower and seeds are produced quickly, enabling a better spreading to the surrounding area. It seems that burning the weedy grass improves its ability to produce more aboveground biomass *(Lojka, pers.comm.)*.

Chemical method of repressing this weed is effective but the chemicals are not friendly to the other vegetation and causes biodiversity losses too.

Chemical method of repressing this weed is effective but the chemicals are not friendly to the other vegetation and causes biodiversity losses too. The chemicals are also expensive and inaccessible for the poor farmers.

There are more ecological methods to control *Imperata*. Lojka *(pers.comm.)* said that the use of shade trees in a kind of agroforestry design is the most promising method for small farmers for control of *Imperata* grasslands. It increases species diversity, provides soil restoration and also shade, which is not suitable for *Imperata* weed. A report from Hairiah et.al. (2000) states that *Imperata* was above ground biomass decreased by more than 50 % after eight months under 88% artificial shading. Well applied shade tree management can be very helpful in the *Imperata* weed control.

2.4.2. Agroforestry systems and biodiversity

Agroforestry is a modern name for land-use system which combines tree and crop plantation. Individual components of this system have ecologic and economic relations. Agroforestry is defined by the International Center for Research in Agroforestry (ICRAF, 1993) as a collective name for land-use system and technologies, where woody perennials (trees, shrubs, palms, bamboos, etc.) are deliberately used on the same land management unit as agricultural or temporal sequence. In agroforestry system there are both ecological and economical interactions between the different components. Leakey (1996) defines that agroforestry should be reconsidered as a dynamic, ecologically based, natural resource management system that, through the integration of trees in far land rangeland, diversifies and sustains production for increased social, economic and environmental benefits.

Agroforestry optimizes crop and animal production of poor smallholders. Actually the offer of products for indigenous people increase by producing multipurpose trees and combinations with domestic animals and fishery. Modern ways of agroforestry allows increasing and maintenance of soil fertility and positive microclimate. There are lots of agroforestry systems, for example agrosilvicultural, silvopastoral and agrosilvopastoral. These are used for rational farming in developing countries (*Table no. 1.*).

Table 1: Classification of agroforestry systems.

Agroforestry system	Concept
Agrisilviculture	Crops and trees including shrubs
Silvopastoral	Pasture animals and trees
Agrosilvopastoral	Crops, pasture animals and trees
Other	Multipurpose trees, agriculture and trees, aquaculture and trees

(Source: Young 1999*)*

There exist also proven impacts of agroforestry, for example: a) Reduction of the poverty by increased production of agroforestry products for home consumption and sale. b) Contributing to food security by restoring farm soil fertility for food crops and production of fruits, nuts and edible oils. c) Reducing deforestation and pressure on woodlands by providing fuel wood grown on farms. d) Increasing diversity of on-farm tree crops and tree cover to buffer farmers against the effects of global climate change. e) Augmenting accessibility to medicinal trees (References online, [6]).

Agroforestry is drawing a great expectation in the development of the sustainable forest-friendly food production in Amazon Basin. Snell (1994) declares that for agroforestry practices to be widely accepted and integrated into existing agricultural enterprises, farmers must be able to accomplish them safely, efficiently, and with tools already available at the farm. Agroforestry practices must be friendly to the farmer, budget, and land. According to De Jong (1995) there are some agroforestry systems practicing in the Peruvian Amazon near Ucayali river. The most widespread type of agroforestry "forest gardens" were very variable and characterized by age, dominant fruit, forest tree species and other crop plants and its origin. Only several cultivated woody species were present in all types of forest garden and they were mostly native fruit trees as *Rollinia* sp., *Pouteria caimito*, *Inga edulis*, *Bactris gasipaes*, *Musa paradisiaca*, *Poraqueiba sericea*, and *Pourouma cecropifolia*. Tree species used for timber or construction purposes occurring in forest gardens were *Cedrela odorata*, *Vismia angusta* and *Calathea* sp., which is grown for it leaves, used for wrapping. Also the pastures under trees and multipurpose-tree plantation is developing

As written before, agroforestry increase the nutrient amount in the soil and provides a good microclimate for the vegetation. By these good conditions not only plant species diversity, but also the amount of the animal species increases. Most common species in agroforestry are birds, small vertebrates and invertebrates (spiders and insects). In agroforestry systems, there are less insect pests than in the traditional agriculture land-use systems, because many natural regulators of the pest species are living there (predatory spiders, ants, etc.)

2.5. Insects of the Amazonian rain forest

Amazonian rain forest forms a unique ecosystem, which provides habitats for more than 65% of world's animal and plant species. There are living approximately 50 thousand described insect species which were, but the real number including the expected non-described species could be higher. Insects form an important group for the topical ecosystem. There are significant not only as a component of complex food chain but also for the ecosystem development. There ale lost of herbivore, predatory, parasite ad decomposer species in the forest. Each group has its position and importance in the ecosystem and representatives are well adapted to the environment. According to specific adaptations, there are close interactions developed among insects and rain forest. Closely related species are more sensitive for the forest disturbation and transformations frequently. Most of the species are extinct before the scientific description.

One of the most significant and most abundant insect families is ant family *(Formicidae)*. Ants are worldwide overspread and adapted on different conditions and vegetation structure. Ants (*Formicidae*) represent significant family of the *Hymenoptera* order. There are about 15000 species of ants living on the Earth (Hölldobler and Wilson, 1990). Representatives of this family are overspread worldwide, but in the Neotropical and African areas have a greatest number of endemic genera (Bolton 1994). Ants are living in numerous, well organized colonies and are territorially very frequent. Ants form very important taxon in the Amazon Basin. For example, one third of the entire animal biomass of the Amazonia *terra firme* rain forest is composed of ants and termites, on one hectare of soil live more than of 8 million ants and 1 million termites (Hölldobler and Wilson, 1990). Ants are essential components of ecosystems not only because they constitute a great part of the animal biomass, but also because they act as ecosystem engineers and play one of the main roles in invertebrate biodiversity also in agriculture land use systems.

The highest ant biodiversity is described in the natural and secondary forest but also agroforestry systems provide good conditions for the ant occurrence. There are two main groups of ants in the ecosystem: the soil ants and the canopy ants. Soil ants may belong to the different trophic levels (leaf-cutter a harvester ants as primary consumers; predators and melivors as secondary consumers), all can be classified as ecosystem engineers (Jones et al., 1994). Ants also improve the soil conditions. Construction of ant nests changes the physical and chemical properties of the soil increasing its drainage and aeration by the formation of underground galleries, and transforming organic matter and incorporation nutrients by food storage, aphid cultivation, and the accumulation of faeces and corpses (Brian, 1978). In the case of non-mound nests the aeration and porosity of the topsoil and subsoil is very high. Also the higher amount of nutrients is caused by the ants, which are burying the organic matter deep in the soil to the special galleries that also act as the water reservoir. Leaf-cutter ants can be determined as the pests, because can cause large damage on the crop and tree foliage, but they are burying the organic matter to the soil structure and provide nutrition for the tree roots. Ant shade tolerant species, occurred in the agroforestry systems forms one of the important factors of the system development to sustainability. In agricultural fields with higher density of ant burrows the soil is more homogenized with lower bulk density. Ants are changing also the chemical soil conditions by the pH buffering and, by changing the soil characteristics, provide better conditions for the vegetation development and in this way also the habitats for other organisms. These changes depend on the ant colony size and temporal and spatial distribution. Predatory ants are also partly affecting the pest populations and by this are very subservient.

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3. Study area

For this study, the area of city Pucallpa was chosen.

It lies in the Amazon basin near the eastern border with Brazil (*Figure 9*), 860 km far from the Peruvian capital Lima. The town has a good position by the river Ucayali – it provides more possibilities for transportation and market. Pucallpa lies in the Peruvian part of the Amazon basin, which is characterized by its hot and humid climate. Temperatures don't vary a lot during the year; the average annual temperature is 25.5 °C and fluctuates only in the range of 6°C. There are two seasons changing during the year: wet and dry. Wet season is from January till April / May and is also the coldest. The dry season lasts from May till November / December and these months are warmest of the year. Precipitation in the major part of Ucayali region is 1,500 mm and humidity fluctuates between 75 – 85%.

Figure 9: Map of Peru (References online, [7])

For this locality humid tropical forest is typical, but during last decades, large area has been deforested. Deforestation is caused also by the farmers, who are slashing and burning forest vegetation to get new plots. Shifting cultivation is sustainable only in an adequate fallow period to renew the forest vegetation and soil fertility restoration. Nowadays Pucallpa has approximately 350 000 inhabitants and the soil is under a big pressure. High food demand causes shortening of the fallow period and soil fertility is rapidly decreasing. People are stumping other hectares of the forest and the process goes on. The land use systems around Pucallpa are heterogeneous, with some settlers developing small-scale cattle ranches, and others practicing slash-and-burn agriculture with perennial crop establishment and substantial proportions of land left in fallow (Fujisaka and White, 1998). There are upland rice, maize, cassava and beans cropped under traditional agriculture. In agroforestry systems the fruit, fuel wood, medicinal or multipurpose trees in combination with pineapples and other crops are cultivated. The cattle ranches are expanding during last decade, but pastures for cattle ranching in the Amazon have suffered from soil degradation. For example, many pastures around Pucallpa have been infested with *Imperata spp.*, (Fujisaka and White, 1998).

4. Objectives

This investigation was realized under the project "Sustainable management of natural sources in Amazonia, Peru" carried by the Institute of Tropics and Subtropics of The Czech University of Life Sciences (CULS) in the frame of Czech Development Program.

The main objective of this study was the assessment of insect biological diversity on various land use systems in Peruvian Amazon. For the research two villages near to the Pucallpa city were chosen, because various traditional land use systems are represented and also the modern agroforestry systems were applied there. Various land use systems and young secondary rain forest reaching relatively small area provides good conditions for the biodiversity assessment and further evaluation. For the research class *Insecta* was chosen because it is quite easy to capture the representatives by using standard entomological methods (pitfall traps, sweeping net.). Insects as a total biodiversity indicator can be comprehended, but there are also other factors affecting the total zoological biodiversity of given locality (type and density of the vegetation cover, local climate, human activities, etc.).

The research on agroforestry fields was based on several investigations that deal with the hypothesis that agroforestry techniques contribute to increase in biodiversity. Other localities (two degraded sites covered by weed vegetation, monoculture cropping and secondary forest) were used for the comparison. In addition to the main biodiversity research, the assessment of the ant diversity and their nest density was done on the chosen localities.

Main objectives of this research were to describe the role of ants in tropical ecosystems and possibility of pests control by ants. On this fundamental following hypotheses ($H^{1\text{-}6}$) were formulated:

H_1: Insect biodiversity and species richness is higher in secondary forest than in the other monitored localities.

H_2: Insect biodiversity and species richness is higher in agroforestry systems than in monoculture and degraded soils.

H_3: In agroforestry systems there are fewer pests than in monocultures.

H_4: In the weed vegetations, there are fewer ant species and also lower number of ant burrows than in agroforestry systems.

H_5: Dominant ant species are controlling the occurrence of other *Formicidae* species on the degraded soils.

H_6: Ants are partly controlling pest species occurrence.

The data obtained in this research are valuable indicators of the environment situation and evolution according to an agricultural activity in the region and will be used for the following investigation in the frame of the CULS`s project. The research also assists in determination of agricultural pests and its likely elimination. Moreover it supports modern entomology, which has a lack of data concerning Peruvian Amazonia region. (On this account the cooperation with Academy of Sciences of the Czech Republic, Entomological, Charles University in Prague and National Museum was dealt).

5. Methodology

5.1. Site description

The research has been executed in Peruvian region Ucayali, nearby Pucallpa town. There are two villages near Pucallpa: Antonio Raimondi and Pimental, where the data were collected. The best localities for data collection were in Antonio Raimondi and Pimental, because we have found there variety of land-use systems – close together monoculture fields, agroforestry fields, nearby secondary forest and the areas overgrown with weeds (plentiful problematic species *Imperata sp.*).

Antonio Raimondi is located 19 km form Pucallpa and 7 km far from the main road to Lima (S 8°22´, W 74°42´). It was established 16 years ago with about 27 households. Nowadays it has approximately 200 inhabitants, shifting farmers, who have already cut down large forest areas around village and they are cutting more of the rest of the forest to establish new plots for cassava etc. Wide degraded areas are covered by the weed species (*Imperata sp.*).

Pimental is a small hamlet situated 35 km far from Pucallpa and 6 km of the main road (S 8°31´, W 74°46´). This village is older than Antonio Raimondi and nowadays it has approximately 390 inhabitants. Land use system is based on the shifting cultivation with pepper (*Piper nigrum*) plantations. Soils are nutrient limited and prone to erosion, but still sustainable for forest production.

In both villages not only traditional agroforestry systems are used but also improved agroforestry systems were implemented here since 2003 by the project of the Czech University of Life Sciences.

5.2. Data collection

5.2.1. Preparation for data collection

The assessment of the biological diversity was realized by using certified methods. There were six localities under different land-use system chosen around Pucallpa: two agroforestry plots, monoculture cropping - cassava, two degraded sites with weed vegetations and the part of young secondary forest for the comparison were selected.

There was quite dense vegetation in the young secondary forest. The microclimate was humid and supported by the fully shaded ground. Estimated age of the tallest tress (cca. 5m) was approximately 10 years. Here was the highest species richness and diversity expected. High diversity and richness values were awaited also in the agroforestry plots. There were two, similar aged, but vegetation different agroforestry systems, chosen for the investigation. One was based on the combination of *Inga edulis* with other trees and pineapples. In the second one, the plantation of *Guazuma crinita* and *Piper nigrum* was developed. As the representative plot of monoculture the *cassava* field was used. This vegetation wasn't shaded and infested by weed on the plot borders. Localities ranked with weeds were divided into two groups according to the density of plant cover (low and high density of vegetation.) The most common weed was *Imperata spp*.

The terrain and vegetation description was done by documentation of the following factors *(Table 2)*:

a) Measurement of the chosen localities for total biodiversity assessment (10 by 10 meters) and its marking.
b) Measurement of the localities chosen for the ant diversity and burrow (nest) density research (5 by 5 meters); and its marking.
c) Type and density of vegetation cover on selected locality.
d) Percentage of the shadow on marked localities.

Table 2: Habitat type description

Habitat type	Habitat description	Village	Site codes
Secondary forest	App. 10 years old forest vegetation. Well grown trees and palms with shrubs and rare ground vegetation. Thick layer of fallen leaves and woody material. Closed canopy layer 5 m. Approximate tree density – up to 9 trees/ 25 m^2. Shade on 95 % of the area.	Pimental	YSF
Agroforestry system Type A	Combination *Inga edulis* trees with pineapples. Tree vegetation density up to 5 trees / 25 m^2. Trees up to 6 m high. Layer of fallen leaves. Shade on 75 % of the area. App. 3-4 years old system.	Antonio Raimondi	AFS-A
Agroforestry system Type B	Combination of *Piper nigrum* and *Guazuma crinita*. Trees up to 12 m high. Vegetation density: 6 trees / 25 m^2. Shade on 50 % of the area. App. 3-4 years old system.	Pimental	AFS-B
Monoculture	Cassava (*Manihot esculenta*) Vegetation density: low No shade.	Antonio Raimondi	MC
Weed vegetation (low spatial plant density)	Plentiful species *Imperata sp.* Rare vegetation. No shade on the ground.	Antonio Raimondi	WL
Weed vegetation (high spatial plant density)	Plentiful species *Imperata sp.* Compact 1,20m tall vegetation. Shade 100% of the ground.	Antonio Raimondi	WH

5.2.2. Data collection (insect snaring)

Insect collection has been realized from June to September in 2007 always in the morning at 8 am by using the same methods in all localities. During these months the dry season culminates and semi-arid seasonal climate conditions are affecting the insect occurrence, mainly the abundance. For the collection only effective and relevant methods were used, especially catching with an entomological net and ground-based pitfall traps with fix-solution. Yellow pan water traps were not used because of problems with domestic poultry kept by nearby farmers. It was impossible to close the omnipresent poultry in some henhouse to prevent eating up the insect samples from the yellow pan water traps. Ants for the supplementary research were captured directly to the fix-boxes without special traps.

a) Pitfall traps

This method is suitable especially for catching terrestrial insect species and is standardly used for entomological investigations (Schulze et al, 2005). Pitfall trap is patterned with its special ground installation (*Figure 11.*). The trap is composed of the plastic cup (12 cm in diameter and 14 cm deep) embed to the neck in the soil and partly covered with a lid to prevent the rain. Traps were installed diagonally on the field *(Figure 10.)* and laid always for 24 hours. Catch from each locality/field was sluiced with fresh water on the sieve and stored in a special plastic box. Boxes were marked with the locality label (*Table 3*).

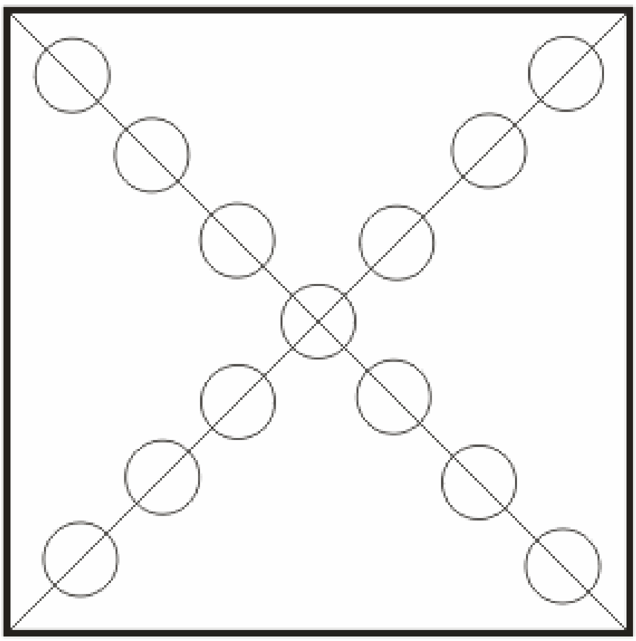

Figure 10: Illustration of the trap position on the selected area.

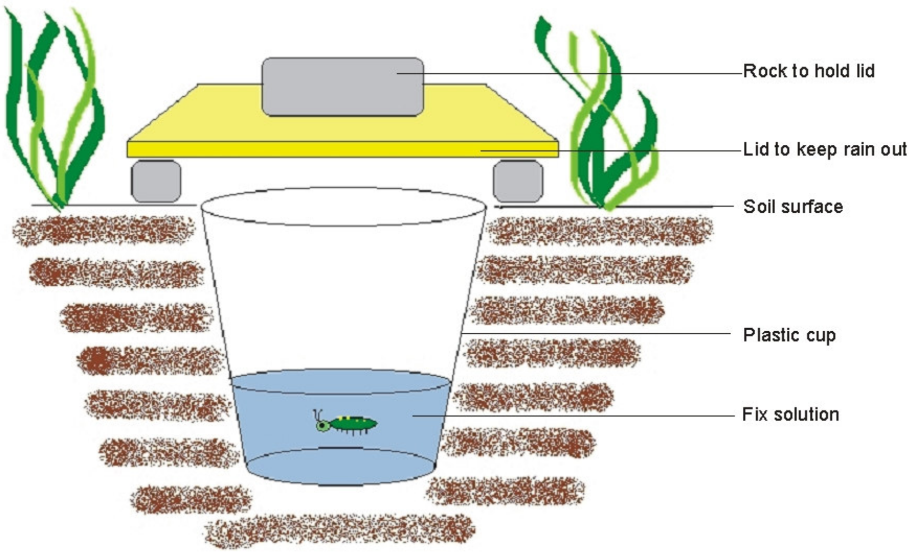

Figure 11: Pitfall trap.

b) Sweeping net

Sweeping net allows catching insect easily and quickly. It is the most common moving trap intended for catching insect species occurred on herbaceous plants (Kubík and Barták, 2004). Trap is a conical net fixed on a metal orb with a handgrip (*Figure 12*). The purpose is to assess the catch in 24 slides.

Every catch was fixed by alcohol (70%), which is also conserving the material, stored in a special plastic box and properly marked with the locality label.

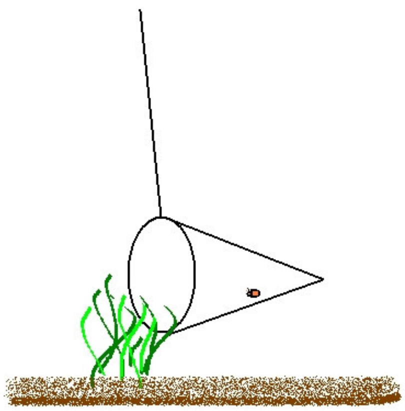

Figure 12: Sweeping net

c) Ant biodiversity and burrow (nest) density assessment

The specific methodology for the research realization was chosen. In each plot, the square 5 by 5 meters, was selected and marked. These plots were divided to the partial squares of $1m^2$ size. In each square the ant burrows were calculated and marked in the terrain plane. Each burrow was disturbed by the wooden stick or by the sugar. A sample of ants from each burrow was collected to the fix box, properly marked and conserved by the alcohol 70%.

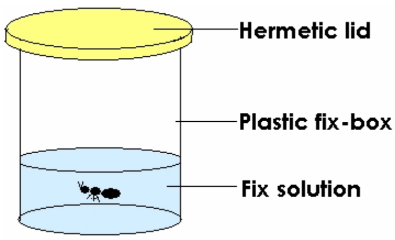

Figure 13: Fix-box for ant collection

5.2.3. Manipulation with the material in the terrain conditions

Collected insects from traps were sluiced with fresh water on the sieve again (ones or twice) and partly dried in the dark room.

Main preserving agent for the long lasting fixation for all samples was pure alcohol 70%. Alcohol is the best conservation for transportation of dead insect material and for further identification in laboratory. For transportation laboratory tubes with a hermetic lid were used. Each tube was properly marked by the locality label (*Table 3*).

Table 3: Locality label

Number of the sample		Type of vegetation	
Date		Locality	
Time		Method of catching	
Notes			

For marking samples pencil were used – is water resistant and records are readable for a long time and labels were printed by laser printers.

5.2.4. Manipulation with the material in the laboratory conditions

Each example was firstly purified (small soil and plant remnants were taken out) separated into small plastic Ependorf's test tube, marked by the locality label and fixed by the pure alcohol 70%. Samples were spitted into basic taxonomy orders (*Colleoptera, Diptera, Heteroptera, Homoptera, Hymenoptera (also Formicidae samples), Isoptera, Odonata, Orthoptera etc.*) and number of species and specimens calculated. All the samples were classified with assistance of professional entomologists.

5.3. Methodology of data evaluation

Total numbers of collected specimens / species were recorded to the table firstly *(Appendix A – A1).* There standard statistic methods to set following indexes (Spellerberg,

1995) were used, by which we can calculate biological diversity and other indexes of specific site.

5.3.1. Occurrence % (O) – percentage of specimen occurrence in chosen localities

The counts were inserted into the table to make (the minimal and maximal) occurrences of species visible in comparison to the other species.

$$Oi = (N/TN) * 100$$

(TN – total number of specimen of one order in all localities, N – number of specimen of order in a given locality, Oi – Occurrence of i^{th} *species.)*

5.3.2. Species density (C) – total number of species per area unit.

$$C = Nd / a$$

(Nd – total number of species of given locality, a – area of given locality in m^2*)*

5.3.3. Abundance (A) – density of the societies.

It is a number of all specimens of all species of given locality.

Accuracy of abundance depends on the monitored biotope and good selection of the collection areas.

$$A = \sum N$$

(N – number of specimen in given locality)

5.3.4. Diversity (D, E) – Taxonomic diversity is a structurally-quantitative characteristic of the society and represents number of species – specimen ration. The unit is the diversity index, very often is used following:

Simpson`s index of diversity(D):

$$D = 1 / \sum pi^2$$

$$pi = Ni / N$$

Simpson’s index of equitability (E):

$$E = D / Nd$$

(The symbols are the same as in previous indexes)

The diversity index is lowest when all specimens are of one species. And reversely the diverzity index is highest when each specimen ranks to the different species.

5.3.5. Margalef`s index of species richness (P) – express richness of the species depending on the number of specimens. The higher resultant value (P) is the species richness greater.

P = (Nd - 1) / log N

5.3.6. Index of similarity (S) is standardly used for the locality comparison.

S – [2C / (A + B)] * 100 (%)

A – number of species in the locality A

B – number of species in the locality B

C – number of species occurring simultaneously in locality A and B.

5.3.7. Total density of ant burrows on the selected area (BC).

BCi = b/a

b – total number of ant burrows, a – area, i – number of the locality

5.3.8. Number of species of the locality

Total number of species collected in the given locality (Nd).

Ndi = Σ N
N – Number of species, i – number of locality

5.3.9. Dominant species (DOA) – dominant ant species.

There were the numbers of borrows calculated for each species in a given locality. The species, which occupies higher number of burrows, is the dominant species of selected area. Results are highlighted in the *Table 8*.

6. Results

From the abundance the percentage occurrence of all orders were calculated and expressed in the table 4.

6.1. Occurrence % (O)

The representatives of the *Orthoptera-Acrididae* and *Homoptera* orders as the pests were determined, because (adults and also juvenile stages) are causing large damages on the plants. From the table the lower occurrence of pest species is visible in the agroforestry systems, contrary to the monoculture plantation and weed vegetations, where higher percentage of pets is.

Table 4: The occurrence (% of specimen) of the insect order s in various land use systems.

YSF-young secondary forest, AFS A and B – agroforestry systems, MC – monoculture, WL – weed vegetation with low plant density, WH – weed vegetation with high plant density.

	YSF	AFS-A	AFS-B	MC	WL	WH
Orthoptera - Tettiginidea	4.1	8.2	6.1	20.4	23.5	37.7
Orthoptera - Acrididae	26.6	6.7	20	26.7	6.7	13.3
Homoptera	17.5	7.21	6.19	25.8	14.4	28.9
Heteroptera	11.3	18.9	18.9	13.2	18.9	18.9
Hymenoptera	24	14	8	16	22	16
Hymenoptera - ants	24.8	30.4	18.9	10.3	6.96	8.64
Diptera	18.2	27.1	14.9	6.08	6.08	27.6
Coleoptera	30.5	9.27	26.5	13.9	8.61	11.3
Odonata	87.5	0	12.5	0	0	0
Mantodea	100	0	0	0	0	0
Thysanoptera	57.1	21.4	21.4	0	0	0
Blattodea	50	0	0	25	0	25
Neuroptera	100	0	0	0	0	0
Grilloidea	0	0	0	50	25	25

The highest occurrence of the pests was in the monoculture and weed vegetation (WH): *Orthoptera-Acrididae* 26.7 % and 13.3 %. *Homoptera* species were mostly abundant in the monoculture 25.8 % and in weed vegetation (WH) 28.9 %. High percentage of pests on the monoculture fields and weed vegetations can be explained by the lots of food sources and lower competition. On the other hand, in the young secondary forest and agroforestry systems there are lots of food sources, but there are not so suitable conditions and is a great competition and high developed food chain with lots of predators.

Odonata and *Thysanoptera* species were collected only in the young secondary forest and agroforestry systems, because it is more humid, there are more food sources and less human disturbation. Not too abundant orders *Mantodea* and *Neuroptera* species were trapped only in the young secondary forest. Representatives of the orders *Grilloidea* and *Blattodea* were collected in the monoculture and weed vegetations, but *Blattodea* also occurs in the young secondary forest.

6.2. Species density, abundance and species richness

The highest species density 0.81 sp/m^2 (according to the number the species) and highest abundance (242 specimen) in the young secondary forest was observed. In the other hand, the lowest density 0.41 sp/m^2 was recorded in the monoculture and smallest abundance constitute 112 specimens in the weed vegetation with low spatial plant density (WL). The highest species richness was in the young secondary forest 33.6 and the lowest one in the monoculture cropping (18.6). Agroforestry systems show the relatively high density and abundance. The species richness in the agroforestry systems was higher than in monoculture and degraded sites with weed vegetation.

Table 5: Species density, abundance and Margalef`s index of species richness.

According to the number of the species (Nd), the species density (C) was calculated. Abundance (A) shows the number of specimen in each locality. Species richness (P). YSF-young secondary forest, AFS A and B – agroforestry systems, MC – monoculture, WL – weed vegetation with low plant density, WH – weed vegetation with high plant density.

	Number of the species (Nd)	C	A	P
YSF	81	0.81	242	33.6
AFS-A	64	0.64	208	27.2
AFS-B	54	0.54	169	23.8
MC	41	0.41	142	18.6
WL	42	0.42	112	20.0
WH	52	0.52	187	22.5

6.3. Diversity and equitability

The results of the diversity and equitability calculations are presented in *Table 6.* The highest indexes of diversity were surprisingly calculated in weed vegetation with low plant density (WL) 28.8 and young secondary forest (YSF) 28.5.

The equitability was highest in the WL vegetation (0.68). The lowest values of species diversity and equitability were in both agroforestry systems with diversity mean ~ 28.6 and equitability 0.3.

Table 6: Species diversity and Equitability

D – Simpson's index of species diverzity, E - Simpson's index of equitability
YSF-young secondary forest, AFS A and B – agroforestry systems, MC – monoculture, WL – weed vegetation with low plant density, WH – weed vegetation with high plant density.

	D	E
YSF	28.5	0.35
AFS-A	18.6	0.29
AFS-B	18.3	0.3
MC	25.7	0.62
WL	28.8	0.68
WH	24.6	0.47

This distortion is supposedly caused by the insect collection during the dry season. Arid conditions and lower humidity in the natural and agroforestry vegetations are limiting for the insect abundance. Lower abundance is distorting then the diversity index. On the other hand, agro-/antropo-tolerant insect species (mostly pests) are not too sensitive to the climate changes and can survive on the monocultures and degraded soils infested by weeds. One of the reasons of high diversity on the WL locality can be also caused by the presence of enough food sources.

6.4. Index of similarity (S)

For each locality the index of similarity was calculated *(Appendix A – A2)*. The main indexes are expressed in the following graphs *(Figure 14, 15)*.

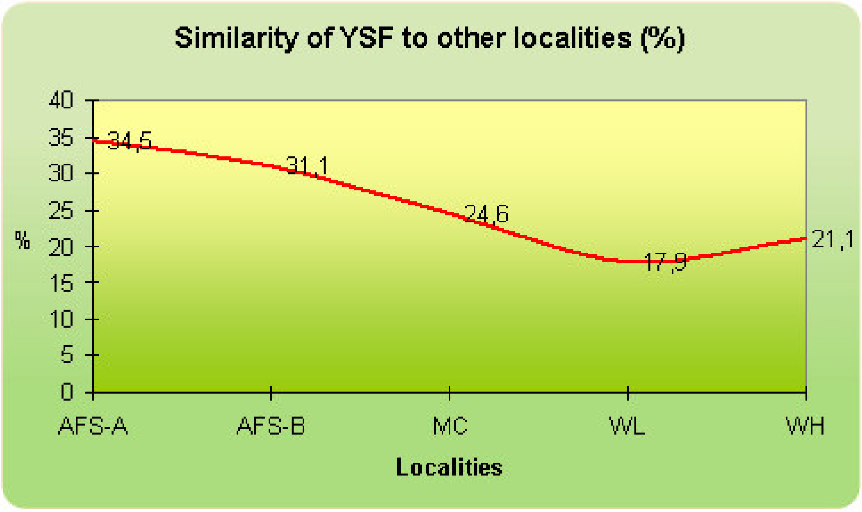

Figure 14: Similarity of young secondary forest (YSF) to other localities.
AFS A and B – agroforestry systems, MC – monoculture, WL – weed vegetation with low plant density, WH – weed vegetation with high plant density.

The similarity of species occurred in the young secondary forest (YSF) is highest to the agroforestry systems AFS-A (34.5 %) and AFS-B (31.1 %). Low percentage of similarity was to weed vegetations WL (17.9 %) and WH (21.1 %).

.

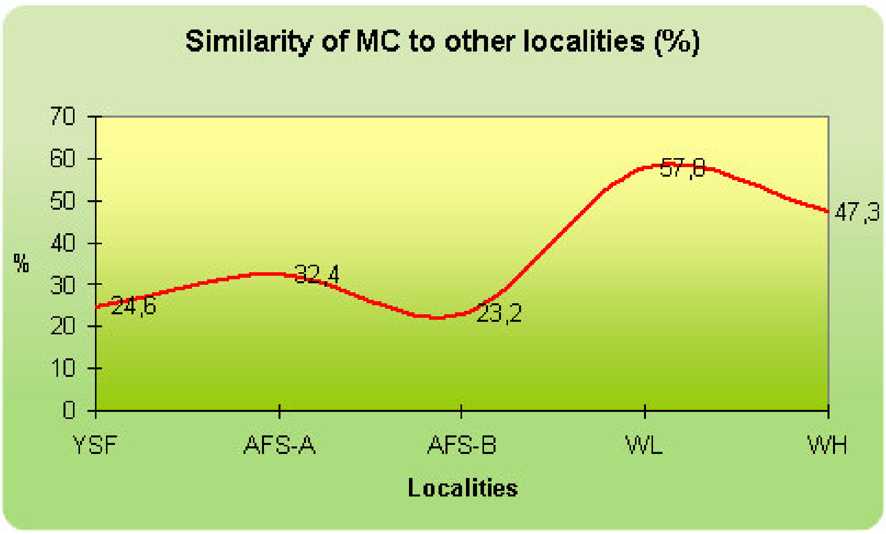

Figure 15: Similarity of monoculture plantation to other localities.
The abbreviations are the same as in previous graph.

Data from the graph shows the extremely high similarity of monoculture plantation (MC) to the weed vegetations WL (57.8) and WH (47.3). To the contrary, the lowest similarity of species structure was to the young secondary forest and both agroforestry systems (from 23.2 to 32.4). In all six localities, there are only 2 species occurring simultaneously, and then the total similarity is 1.19 %.

6.5. Total burrow density and number of species of ants in chosen localities.

Table 7.: Total burrow density and number of species of ants in each locality

AFS A and B – agroforestry systems, MC – monoculture, WL – weed vegetation with low plant density, WH – weed vegetation with high plant density.

Vegetation type	Total burrow (nest) density (BC)	Number of species (Nd)
WL	0.44	2
WH	0.52	3
WH/MC	0.68	3
AFS-A	0.84	5
AFS-B	0.76	4

The total burrow density and number of species of ants in the YSF wasn't assessed because this part of research is focused mainly on the agricultural land use systems and degraded site covered by weed vegetations. According to the results of the ant burrow density and number of species calculations is visible the high difference mainly between the locality WL and locality AFS-A. On the locality AFS-A the highest burrow density (0.84) and also the number of species (5) was established. On the contrary to the locality WL is quite poor, is occupied only by 2 species and the burrow density (0.44) is also the lowest of all assessed localities. These numbers can be explained by the affecting of external natural factors, for example the percentage of shade on the ground, soil humidity and quality and also the food sources. 74% of area on the locality AFS-A is shaded by the tree vegetation; agroforestry system also provides better soil conditions (humidity, structure) than the degraded soil in the case of weed vegetation. Species on the locality AFS-A are represented mainly by the predatory ant species with different nutrient requirements. This species structure is one of the factors which can eliminate pest species (*Orthoptera – Acrididae* and *Homoptera* species.).

6.9. Dominant species

Ant burrows were signed in locality plan, each burrow was disturbed and representatives collected. The number of burrows for each species was calculated *(Table 8)*.

Table 8: Number of burrows (of each species) in selected localities

Morpho species are described by abbreviations, detail taxonomy submission is described in the Appendix A1. AFS A and B – agroforestry systems, MC – monoculture, WL – weed vegetation with low plant density, WH – weed vegetation with high plant density.

Morpho sp.	WL	WH	AFS-A	AFS-B	WH/MC
Myrmicin 1	**7**	**9**	**10**		**12**
Myrmicin 8	4	3	6	3	3
Dolichod 10		1			2
Ponerin 2			3		
Dolichod 14			1		
Formicin 9			1	2	
Dolichod 3				**10**	
Ponerin 4				4	

According to the numbers in the table 8, the morpho sp. *Myrmicin 1* is dominant in locality WL (by 7 burrows), in locality WH (by 9 burrows), in locality AFS-A (by 10 burrows) and maximal and total dominancy shows *Myrmicin 1* on locality WH/MC by 12 burrows. Morpho sp. *Dolichod 3* occurs only on the locality ABS-B and here represents dominant species by 10 burrows. On the localities WL, WH and WH/MC the high dominance of morpho sp. *Myrmicin 1* is significant. On degraded soil the morpho sp *Myrmicin 1* can be more aggressive and competitive for food sources and is controlling and repressing other species. Localities AFS-A and AFS-B allow a higher number of species on quite small area by providing more food sources and better habitat.

7. Discussion

The change from natural forest to agroforestry systems is normally accompanied by a significant increase in temperature and cover of the herb layer (Bos et al., 2007) and naturally the vegetation change too. In a direct comparison of abundance, species richness and a diversity index (combining abundance and species richness) between forest and agroforestry sites we quantified faunal turnover and conservation potential of agroforestry systems for different insect groups (Bos et al., 2007). According to the species richness, abundance (*Table 5)* and similarity *(Figure 14, 15)* agroforestry systems around Pucallpa can work as reservoirs for the conservation of those insect species, which are more sensitive to the habitat conditions and occurs only in the secondary forest and agroforestry systems.

Bos (2007) declares that the diversity remained high, species compositions changed drastically from natural forest sites to intensively managed agroforestry systems. In this study, the species composition doesn't change drastically, but this difference can be caused by using secondary forest ecosystem instead the primary forest. But also in this study, the species richness decrease continuously from the highest numbers in young secondary forest to the agroforestry systems further to the monoculture plantation and last to degraded sites covered by weed vegetation where the values were lowest. These results support hypothesis that species richness is higher in secondary rain forest than in other localities (H^1) and also H^2: that the sp. richness is higher in the agroforestry systems than in the monoculture. But the biodiversity values are not supporting the hypothesis H^1 and H^2, because are very variable *(Table 6.).*

Insect collecting for this research was realized during the dry season. There were not so suitable conditions for entomological investigations because most of the insect species are less abundant during this season, but there were best conditions for transport and accessibility to chosen villages. Data of biodiversity (Simpson's index of species diversity) were distorted due to the quarterly climatic conditions. A *table 6* show, the diversity was highest in the weed vegetation (WL) which was evaluated as the poorest one, and in the secondary rain forest. But the species composition was significantly different *(Figure 14, 15)*. As localities with a lowest biodiversity index the agroforestry systems were calculated. Insects were collected during the dry season, which is limiting for most of the anthropo- / agro- intolerant species. Those species occur mainly in the young secondary forest and similar land use systems (in our case the agroforestry systems). The diversity index of the YSF was not significantly seasonally affected, but the agroforestry systems were. Young secondary forest can retain the micro water regime also during the dry season and thereby provide the more suitable conditions for insect. The water regime in the various agroforestry systems change more during the year than in the secondary forest vegetation, so the insect abundance is affected significantly, but the species richness persists without high fluctuations.

Data, presented in the *Table 4*, are supporting the hypothesis H3 that in the agroforestry systems are fewer pests than in the monoculture.

Ants are very abundant and rich in the natural and changed tropical forests and are also the one of the general component of the ecosystem. Bos (2007) declares that by the reduction or complete removal of the shade canopy is usually accompanied by changes in temperature and humidity that may indirectly lead to decreases in particularly ant diversity (Perfecto and Vandermeer 1996; Armbrecht et al. 2005) by favoring ecologically dominant ant species (Room 1971; Gibb and Hochuli 2003), which can even lead to cascades of further biodiversity losses (O'Dowd et al. 2003). Compared to the agroforestry, systems the lowest amount of found burrows and spices number were determined on degraded sites with weed vegetations and the monoculture (*Table 7*). The wealthiest for species and burrow numbers were agroforestry systems. Monitoring of the ant burrow density in the secondary forest wasn't done, because of worse access to the vegetation, data form the YSF could be also biased because of the high numbers of canopy species. The data mentioned above support the hypothesis H^4 that in the weed vegetations, there are fewer ant species and also lower number of ant burrows than in agroforestry systems.

Taking into account that the ant species are usually territorially the hypothesis H^5 can be discussed. From all chosen localities, the most significant dominance of *Myrmicin 1 sp*. over the other species was ascertained. This finding confirms the fifth hypothesis *(H^5**:** Dominant ant species are controlling the occurrence of other Formicidae species on the degraded soils.)*

There is existing lost of ant genera with a different influence on the ecosystem (predatory, herbivore, etc.). For example, the predatory species can decrease the pest species (caterpillars, early stages of various insect species, etc.). According to the *Table 4*, where the lowest percentage of pest species occurrence and also highest percentage of ants is presented, the hypothesis H^6 can be confirmed. Naturally there are lots of factors impacting the pest species occurrence. Ants can partly control the pest species.

8. Conclusion

The tropical rain forest represents a unique natural ecosystem with copious amount of plant and animal species, which is characterized by quite a number of interspecific relations and ties to the environment. Those relations are very specific and their disturbances by human activities are of concern to further ecosystem development. Owing to the deforestation for further agricultural use, the vegetation, temperature and the water regime of the localities were changed.

After the ecosystem disturbations numbers of the species declines significantly. Agricultural intensification and high disturbance levels due to intensified management practices have negative effects on faunal diversity in that a few ‘winner’ species make up a less diverse community at the cost of many ‘loser’ species (McKinney and Lockwood, 1999). On the monoculture fields and weed vegetations, in villages chosen around Pucallpa city, there was far lower species richness than on the agroforestry systems plots and selected part of young secondary forest vegetation. Also the species composition between young secondary forest and agroforestry system was highly similar. From those data we can conclude that agroforestry systems can work as reservoirs for forestall insect species after disturbations. The faunal diversity, indicated by class *Insecta*, was calculated according to the Simpson’s index. The highest value of biodiversity was determined in the young secondary forest and surprisingly also in the weed *Imperata* vegetation. Insect species composition of the degraded sites covered by the weed vegetation was significantly different to the forest one. This event was supposedly caused by the insect collection during the dry season, when more of the anthropo- or agro-tolerant species can survive more abundant than other species. Very interesting was also the high species richness and sp. composition of ants. Ants are very important for the ecosystem development because can improve the soil conditions and affect the environment also as the predators or herbivore animals. They can work partly as natural pest control too.

Results mentioned in this thesis are very important for the biodiversity investigations and following use of the department of agroforestry and crop production (CULS). The thesis forms a good and adequate scientific ground for the further research of biodiversity using entomological assessment for the indication.

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Personal Correspondence

BELL Graham, Director, Redpath Museum*, pers comm.*

Ing. LOJKA Bohdan, PhD., Director of Department of crop production and agroforestry in tropics and subtropics. Czech University of Life Sciences in Prague, *pers comm.*.

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Appendix A

A1: Table of all collected specimen in each locality.

Order	Family	Sp.Subfamily	Morpho sp.	Suma	YSF	AFS-A	AFS-B	MC	WL	WH
Hymenoptera	*Anthoporidae*		*Anth 1*	1				1		
	Braconidae		*Bracon 1*	1	1					
			Bracon 2	1		1				
			Bracon 3	1	1					
	Chalcididae		*Brachymeria sp.*	1			1			
			Chalc 1	1	1					
	Encyrtidae		*Encyr 1*	1		1				
			Encyr 2	1		1				
	Eucotidae		*Euco 1*	1	1					
	Eulophidae		*Eulo 1*	2	2					
			Eulo 2	1	1					
	Eurytomidae		*Eury 1*	2					2	
	Figitidae		*Figi 1*	1			1			
	Halictidae		*Hal 1*	8	4	2	2			
			Hal 2	8				3	2	3
			Hal 3	1				1		
			Hal 4	1					1	
	Ichneumonidae		*Ichn 1*	1					1	
			Ichn 2	3				3		
	Pteromalidae		*Pte 1*	3		1			2	
	Scelionidae		*Sce 1*	2						2
			Sce 2	1						1
			Sce 3	1						1
			Sce 4	2					2	
			Sce 5	1		1				

Order	Family	Sp.Subfamily	Morpho sp.	Suma	YSF	AFS-A	AFS-B	MC	WL	WH
Hymenoptera	*Sphecidae*		*Sphec 1*	1						1
			Sphec 2	1	1					
	Vespidae		*Polist 1*	1					1	
Heteroptera	*Alydidae*	*Alydinae*	*Aly 1*	1	1					
		Subfam:Leptocorisinae	*Lepto 1*	1			1			
		Subfam:Leptocorisinae	*Lepto 2*	1			1			
	Berytidae	*Jalysus sp.*	*Jal 1*	7		4	2		1	
	Coreidae		*Core 1*	6			3		2	1
			Core 2	1				1		
	Lasciochilidae		*Las 1*	1						1
	Miridae		*Miri 1*	3	1	1	1			
			Miri 2	1			1			
	Nabidae		*Nab 1*	1					1	
	Ninidae		*Ninid 1*	3	2	1				
	Pentatomidae	*Euschistus sp.*	*Euschyt 1*	1						1
		Mormidea sp.	*Mormi 1*	11		1		3	4	3
	Reduvidae		*Red 1*	3		2				1
			Red 2	1		1				
	Rhyparochromidae		*Rhypa 1*	8				3	2	3
			Rhypa 2	1			1			
	Schizopteridae		*Schizo 1*	1	1					
	Thyreocoridae		*Thyre 1*	1	1					
Homoptera	*Cercopidae*		*Cer 1*	13			1	2	3	7
			Cer 2	2	1	1				
	Cicadellidae	*Subfam: Agalliinae*	*Aga 2*	13				4	3	6
		Subfam: Cicadellinae	*Cica 3*	12			2	6	4	
		Subfam: Cicadellinae	*Cica 4*	1		1				
		Subfam: Cicadellinae	*Cica 5*	2	1	1				
		Subfam: Cicadellinae	*Cica 6*	1		1				

Order	Family	Sp.Subfamily	Morpho sp.	Suma	YSF	AFS-A	AFS-B	MC	WL	WH
Homoptera	*Cicadellidae*	*Subfam: Cicadellinae*	*C 10*	13				3	2	8
			C larva	7	2			5		
		Subfam: Deltocephalinae	*Del 7*	1	1					
		Subfam: Deltocephalinae	*Del 8*	1	1					
		Subfam: Deltocephalinae	*Del 9*	1	1					
		Subfam: Deltocephalinae	*Del 12*	2		1	1			
		Subfam: Deltocephalinae	*Del 14*	1						1
		Subfam: Ledrinae	*Ledri 1*	1	1					
		Subfam: Stegelytrinae	*Ste 11*	1	1					
		Subfam: Typhlocybinae	*Typhlo 13*	12				5	2	5
	Delphacidae	*Subfam: Delphacinae*	*Delpha 2*	1						1
		Subfam: Stenocraninae	*Steno 1*	3	3					
	Membracidae		*Membra 1*	1		1				
			Membra 2	7	4		1			
			Membra 3	1	1					
			Membra larva	1			1			
	Psocoptera		*Pso 1*	1		1				
Mantodea			*Mantis 1*	3	3					
Thysanoptera			*Thys 1*	14	8	3	3			
Blattodea			*Bla 1*	1	1					
			Bla 2	3	1			1		1
Neuroptera			*Neuro 1*	4	4					
Grilloidea			*Grill 1*	16				8	4	4
Orthoptera	***Tettiginidae***		*Tetti 1*	12	2	2			3	5
			Tetti 2	10			2	2	4	2
			Tetti 3	6		2		4		

Order	Family	Sp.Subfamily	Morpho sp.	Suma	YSF	AFS-A	AFS-B	MC	WL	WH
Orthoptera	***Tettiginidae***		*Tetti 4*	20	2			8	4	6
			Tetti 5	6						6
			Tetti 6	4					4	
			Tetti 7	18			4		6	8
			Tetti 8	22		4		6	2	10
	Acridioidae		*Acri 1*	4	2			1		2
			Acri 2	5		1		3	1	
			Acri 3	3			3			
			Acrida sp.	2	2					
Odonata	*Suborder: Zygoptera*		*Zygo 1*	1			1			
			Zygo 2	2	2					
	Suborder: Anisoptera		*Aniso 1*	5	5					
			Aniso 2	8	7		1			
Diptera	*Anthomyzidae*		*Anthom 1*	8	1	3				4
	Ceratopogonidae		*Cerato 1*	13	4	1	1	5	2	
	Chironomidae		*Chiron 1*	1		1				
			Chiron 2	1		1				
	Chloropidae		*Chloro 1*	80	12	21	18	1	5	23
			Chloro 2	5	1	1	1	1	1	
			Chloro 3	9	7					2
			Chloro 4	1						1
			Chloro 5	1		1				
	Culicidae		*Culi 1*	14	4	6		2		1
	Dolichopodidae		*Doli 1*	6		1		1	1	3
			Doli 2	2	1		1			
			Doli 3	3		1				2
			Doli 4	1		1				
			Doli 5	1		1				
	Drosophilidae		*Droso 1*	1		1				
	Empididae		*Empi 1*	1						1

Order	Family	Sp.Subfamily	Morpho sp.	Suma	YSF	AFS-A	AFS-B	MC	WL	WH
Diptera	*Ephydridae*		*Ephy 1*	6		4	1			1
			Ephy 2	7		2		1		4
	Milichiidae		*Milich 1*	1			1			
	Muscidae		*Musci 1*	1			1			
	Opomyzidae		*Opo 1*	6			2		1	3
	Phoridae		*Pho 1*	1		1				
	Sciomyzidae		*Sciom 1*	4	2	1	1			
			Sciom 2	2						2
	Sphaeroceridae		*Sphaero 1*	1					1	
	Stratiomyzidae		*Strati 1*	1	1					
			Strati 2	1						1
	Syrphidae		*Syr 1*	1		1				
	Tachnidae		*Tach 1*	1						1
	Tephritidae		*Tephri 1*	1						1
Hymenoptera	*Formicidae*	*Dolichoderinae*	*Dolichod 3*	81	24	31	26			
		Dolichoderinae	*Dolichod 6*	7		5	2			
		Dolichoderinae	*Dolichod 10*	15		10		2		3
		Dolichoderinae	*Dolichod 11*	1	1					
		Dolichoderinae	*Dolichod 14*	8	4	3				1
	Formicidae	*Formicinae*	*Formicin 9*	28	4	14	7		1	2
	Formicidae	*Myrmicinae*	*Atta 1*	33	14	5	2	3	4	5
		Myrmicinae	*Myrmicin 1*	33		10		8	6	9
		Myrmicinae	*Myrmicin 5*	28	11	10	7			
		Myrmicinae	*Myrmicin 7*	27	5	7		8	7	
		Myrmicinae	*Myrmicin 8*	30		2	8	7	5	8
		Myrmicinae	*Myrmicin 12*	15			5	7		3
		Myrmicinae	*Myrmicin 13*	1	1					
		Myrmicinae	*Myrmicin 16*	2	2					

Order	Family	Sp.Subfamily	Morpho sp.	Suma	YSF	AFS-A	AFS-B	MC	WL	WH
Hymenoptera	*Formicidae*	*Ponerinae*	*Ponerin 2*	43	20	12	7	2	2	
		Ponerinae	*Ponerin 4*	6	2		4			
		Ponerinae	*Ponerin 15*	1	1					
Coleoptera	*Anthicidae*		*Anthicida 1*	1	1					
	Bruchidae		*Bruchi 1*	18	11		7			
			Bruchi 2	1	1					
	Buprestidae		*Bup 1*	1				1		
	Carabidae		*Carab 1*	1					1	
			Carab 2	1	1					
			Scari	1		1				
	Cerambycidae		*Ceramby 1*	4			2			2
			Ceramby 2	1	1					
			Ceramby 3	1	1					
	Coccinellidae		*Cocci 1*	7	1	1	4		1	
			Cocci 2	1	1					
	Curculionidae		*Curcu 1*	1	1					
			Curcu 2	1	1					
	Elateridae		*Elat 1*	2			2			
			Elat 2	1	1					
	Chrysomelidae	*Subfam: Alticinae*	*Alti 1*	1			1			
			Alti 2	4	3		1			
			Alti 3	4	3			1		
			Alti 4	1	1					
			Alti 5	3			1	2		
			Alti 6	1	1					
			Crio 1	3			2		1	
			Crio 2	2	1	1				
		Subfam: Hispinae	*Hispi 1*	8	4	2	2			
			Hispi 2	1			1			
			Chrysom 1	9	2			3	2	2

Order	Family	Sp.Subfamily	Morpho sp.	Suma	YSF	AFS-A	AFS-B	MC	WL	WH
Coleoptera	*Chrysomelidae*		*Chrysom 2*	1				1		
			Chrysom 3	16	5		11	1		2
			Chrysom 4	2			2			
			Chrysom 5	1	1					
			Chrysom 6	1		1				
			Chrysom 7	1		1				
			Chrysom 10	1	1					
			Chrysom 11	1		1				
	Lathrididae		*Lathri 1*	1	1					
	Mordellidae		*Mord 1*	1			1			
			Mord 2	35	1	3		12	8	11
			Mord 3	1			1			
	Phalacridae		*Phala 1*	4	1	1	2			
			Phala 2	1		1				
	Teneprionidae		*Teneb 1*	1		1				

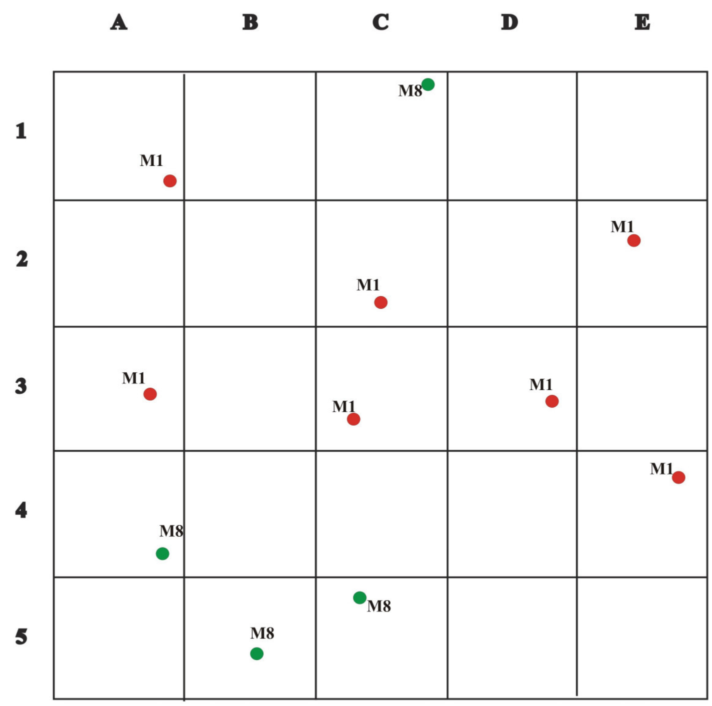
A 2: Index of similarity (S) of insect species among all localities.

	YSF	AFS-A	AFS-B	MC	WL	WH
YSF		**34,48%**	31,11%	24,59%	17,89%	21,05%
AFS-A	**34,48%**		**33,90%**	32,38%	33,96%	31,03%
AFS-B	31,11%	33,90%		23,16%	31,25%	26,42%
MC	24,59%	32,38%	23,16%		**57,83%**	47,31%
WL	17,89%	33,96%	31,25%	**57,83%**		**48,94%**
WH	21,05%	31,03%	26,42%	47,31%	48,94%	

Appendix B

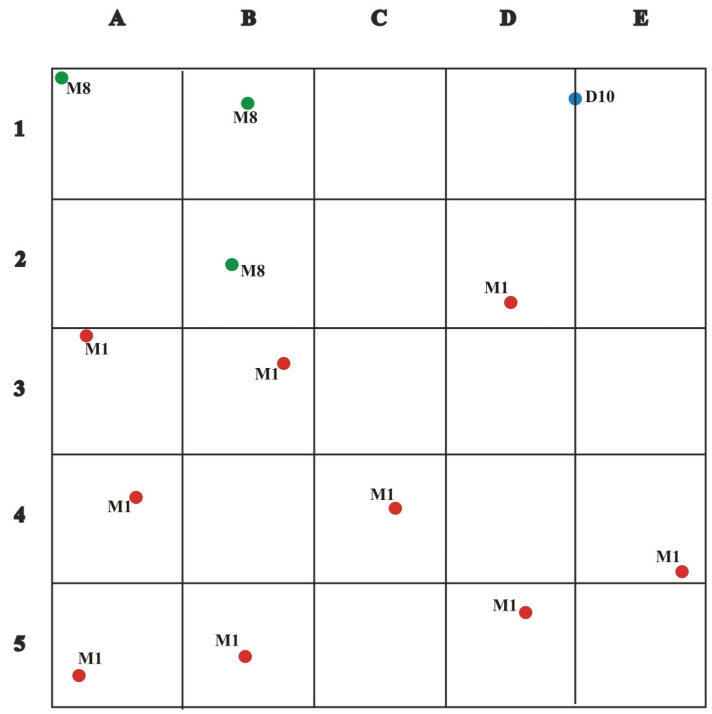
Collected ants (*Hymenoptera, fam. Formicidae*) are representatives of four subfamilies: *Dolichoderinae, Formicinae, Myrmicinae and Ponerinae*.

B1. Ant burrows plan in the *Imperata spp.* vegetation (low density) in Antonio Raimondi.



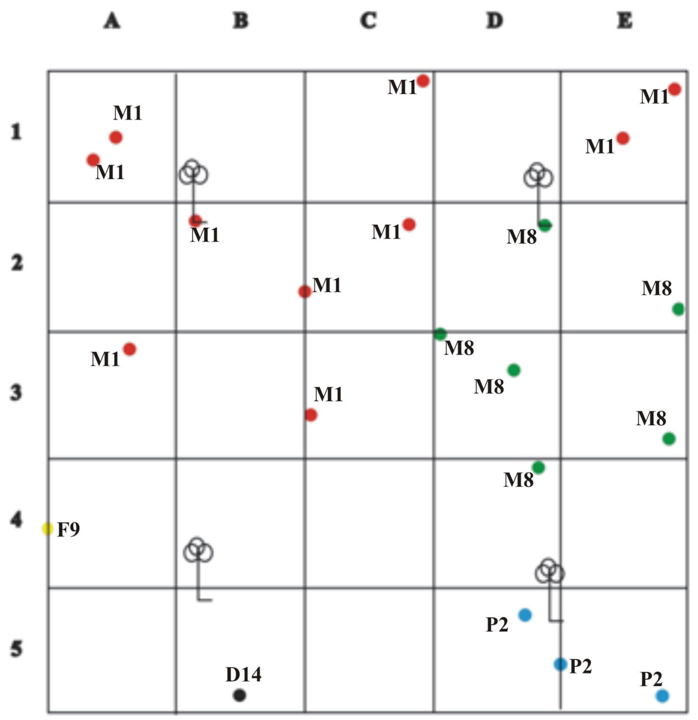
Locality WL		Morpho sp.	Number of burrows
	M1	*Myrmicin 1*	7
	M8	*Myrmicin 8*	4
Total number of species (Nd)			2
Total number of burrows			11

B2. Ant burrow plan in the *Imperata spp.* vegetation (high density) in Antonio Raimondi



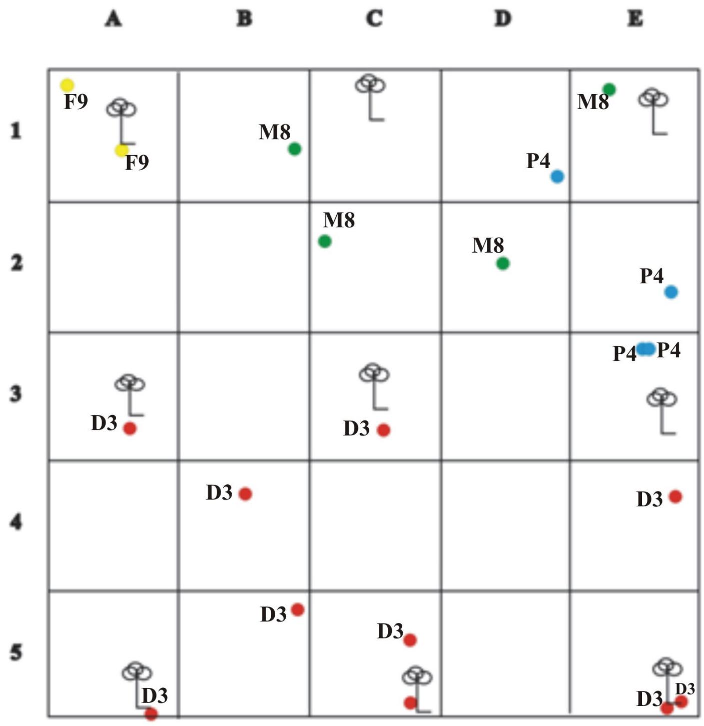
Locality WH		Morpho sp.	Number of burrows
	M1	*Myrmicin 1*	9
	M8	*Myrmicin 8*	3
	D10	*Dolichod 10*	1
Total number of species (Nd)			3
Total number of burrows			13

B3. Ant burrows plan in the afroforestry system (type AFS-A: *Inga edulis)* in Antonio Raimondi



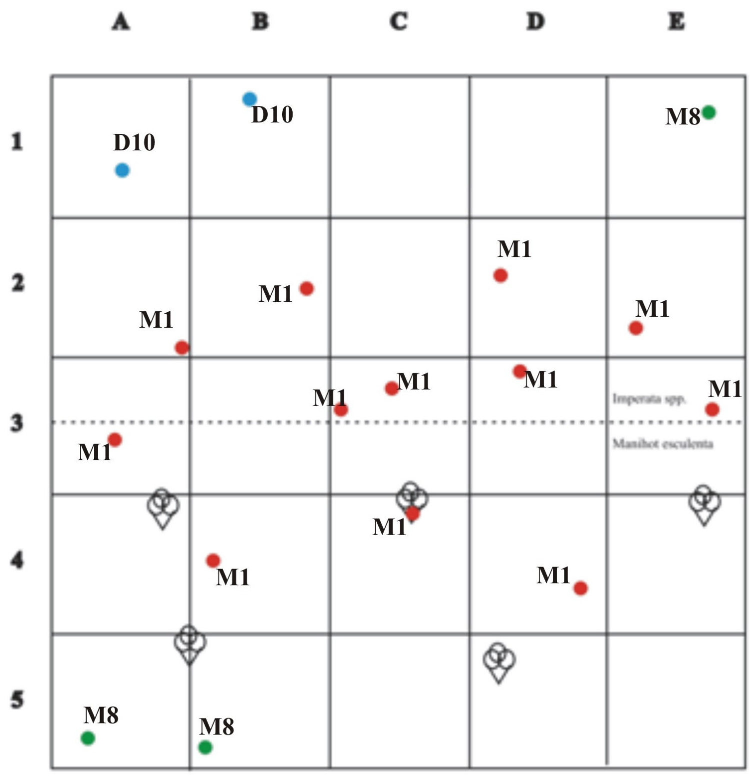
Locality AFS-A	Morpho sp.	Number of burrows
M1	*Myrmicin 1*	10
M8	*Myrmicin 8*	6
P2	*Ponerin 2*	3
D14	*Dolichod 14*	1
F9	*Formicin 9*	1
Total number of species (Nd)		5
Total number of burrows		21

B4. Ant burrows plan in the agroforestry system (type AFS-B: *Guazuma crinita, Piper nigrum)* in Pimental.



Locality AFS-B	Morpho sp.	Number of burrows
D3	*Dolichod 3*	10
M8	*Myrmicin 8*	3
P4	*Ponerin 4*	4
F9	*Formicin 9*	2
Total number of species (Nd)		5
Total number of Burrows		21

B5. Ant burrows plan on boundary of the *Imperata spp*. vegetation and monoculture in Antonio Raimondi



Locality WH/MC		Morpho sp.	Number of burrows
	M1	*Myrmicin 1*	12
	M8	*Myrmicin 8*	3
	D10	*Dolichod 10*	2
Total number of species (Nd)			3
Total number of burrows			17

Appendix C

Localities, where insects were collected.

C1: Agroforestry system (AFS-A) in Antonio Raimondi. Combination of Inga edulic and several pineapples.

C2: Pitfall trap application (preparation for further covering by the lid.) in AFS-A in Antonio Raimondi.

C3: Agroforestry system (AFS-B) in Pimental: Combination of *Guazuma crinita and Piper nigrum).*

C4: Agroforestry system (AFS-B) in Pimental. Detail on *Guazuma crinita and Piper nigrum.*

C5: Cassava *(Manihot esculenta)* monoculture cropping.
References online [8].

C6: Degraded site covered by weed vegetation *(Imperata spp.)* with low plant density (WL) in Antonio Raimondi.

C7: Degraded site covered by weed vegetation *(Imperata spp.)* with high plant density at the back (WH) in Antonio Raimondi.

C8: Part of tropical rain forest after clearing by fire. This area becomes a monoculture cropped field in several days.

C9: Decraded site covered by weed vegetation *(Imperata spp.)* one day after burning.