The Impact of Land Use on Biodiversity in the Framework of Life Cycle Assessment

Master Thesis in Sustainable Development, March 2008

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Abstract

The production, use, and disposal of goods and services generate an impact on the different environmental components. Life Cycle Assessment (LCA) is an important tool that aims at measuring the consequences of this impact in order to offer a base to governmental and non-governmental organizations and stakeholders in the process of environmental decision-making. Land use is one of the impact categories analyzed within the framework of LCA and influences the ecosystem quality of a region. Ecosystem quality is composed of specific characteristics such as biodiversity and ecosystem functions that are crucial towards the survival of mankind.

This work assesses the biodiversity loss caused by land use activities in the Latin American tropical region and develops specific characterization factors applicable in the evaluation within LCA of anthropogenic environmental interventions. The vascular plants species are used as an indicator for the measuring of the whole biodiversity. This choice is supported by previous studies that point out the suitability of this organisms' group for the assessment of land use impact on total species richness.

In order to overcome the lack of data concerning the whole vascular plant species richness in the Latin American tropical region, the analysis is divided into two experimental parts The first part represents the meta-analysis of published empirical data concerning tree species richness in respect to different land use types. The second part is the gathering of experts' knowledge on vascular plant biodiversity through an international survey.

The evaluation of these two data sets leads to a comparable pattern of biodiversity richness depending on the land use activities applied. The more intense the anthropogenic impact the more biodiversity loss one can expect. Consequently, the natural land covers host the higher level of species richness according to both the experts' evaluations and the meta-analysis data, while the most artificial areas display the lowest biodiversity value. The gathered information allows for an evaluation of land use activities in regard to their influence on biodiversity conservation. This evaluation reflects the results obtained from further projects carried out in other Earth's regions and represents a useful tool for the environmental decision making process.

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1. Introduction

1.1. Biodiversity loss

Human activities have changed the environment and its functioning, altering its cycles and flows. These processes trigger modifications of ecosystems and allow the movement of its life parts leading to a transformation of the species composition and species amount in the different Earth regions. It has been calculated that species' disappearance has increased 100 to 1000 fold since human beings walk this earth (Chapin III et al 2000). The largest increase has taken place in the last century.

The loss of species can be attributed to different drivers. An important one is the direct anthropogenic overuse of a species; clear examples of this fact are the over-fishing that decimates the present fish stocks in the oceans or the deforestation of Amazon forest for timber extraction (Jackson et al, 2001; Skole and Tucker, 1993; Mayaux et al, 2005). Other key drivers that accelerate species loss are: climate change (which causes variations in environmental factors and consequently modifies the species habitats (Thomas et al., 2004)), the introduction of exotic species that overcome the endemic species (Hooper et al, 2005) and land use that triggers the destruction of habitats.

Recent studies (Sala et al 2000) investigate future scenarios in respect to species loss and analyze the impact of each driver on the biodiversity of different biomes. The results of these models show that anthropogenic land use (followed by climate change) is the main cause of biodiversity loss predicted for the next century.

Land use already affects biodiversity composition all over the world. However the effects are not equally distributed. Biomes with high species diversity and high human population density are more sensitive to the impact of land use. Whereupon in the future the biome that will suffer more from the changes caused by the anthropogenic land use will be the tropic biome. As a matter of fact the population of tropical countries is increasing at high rates, leading to a greater demand of resources and to an increasing impact on the environment (Cincotta R.P. et al 2000). The fact that land use will mainly affect the tropical regions does not mean that biomes with lower species diversity and smaller human population size, like the Artic and Polar regions, can not suffer from biodiversity loss triggered by anthropogenic land use activities. However it has been observed (Sala et al, 2000) that the species diversity of these biomes is more affected by climate and atmospheric changes.

1.2. Biodiversity as a central component of ecosystems

Biodiversity is a central component of ecological systems. Therefore, it plays an important role in the survival of humankind. Each species living within an ecosystem creates flows of energy and materials. This is the reason why the disappearance of a single species can lead to irreversible changes that alter ecosystem properties. Life diversity maintains the ecological function and allows biogeochemical systems, like the water cycle, the flow of greenhouse gases and the carbon sequestration, to work correctly. At the same time biodiversity directly provides humankind with resources like food, medicines and energy sources. Moreover, some species play a fundamental role within the culture or religion of some human populations. As a result, biodiversity is an irreplaceable good for human kind (Dirzo R., et al 2003).

To counteract biodiversity loss and the peril that this process could entail for humankind the Convention on Biological Diversity was stipulated during the Earth Summit in Rio de Janeiro in 1992. This convention finally assigned a central importance to the biodiversity topic within the framework of environmental problems. The Convention on Biological Diversity supports three main causes: the conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of benefits rising from the utilization of genetic resources (www.cbd.int/sp/). At present, the biodiversity loss is the only environmental problem that is irreversible (Dirzo and Raven, 2003), this is why it is of the highest importance to counteract the extinction crisis and to develop measures that help to control and to foresee the anthropogenic impact on biodiversity.

1.3. Life Cycle Assessment, a tool for the assessment of environmental impact

As mentioned in the previous paragraph human activities like the provision of products and services have a strong impact on the environment. This impact can be either negative or positive. At present we are becoming aware of the importance of preserving the environment and we are developing methods that aim to assess the human impact on ecosystems.

The Life Cycle Assessment (LCA) is one instrument that can help to measure the environmental influence of goods and services. LCA does this by analyzing every steps of their life cycle. These steps include the production of raw materials, the manufacturing of the good or service itself, its transport, its use and its disposal. Each of these steps has an impact on the environment and has to be investigated in detail. This analysis includes an inventory of all inputs and outputs that the generation of a product or service has in respect to the environment. For example, the quantity and sort of resources and energy used, or the amount of gases and radiation released in the atmosphere are catalogued. The components of the inventory are further evaluated and grouped into impact categories.

The results of the Life Cycle Assessment provide the means to compare different alternatives, which enable the selection of the least environmental disturbing or damaging product. This method can also be used to improve an already existing good or service, in order to enhance its performance in respect to the environment.

Life Cycle Assessment is a useful tool in the decision-making process and can be an important support for stakeholders, governmental or non-governmental organizations when facing environmental matters.

1.3.1. Life Cycle Procedure

The procedure of Life Cycle Assessment is divided into four phases. The first phase is the designation of goals and scopes of the analysis to be performed. In this process the boundaries of the analytical model and the impact categories that should be considered are defined. The second step is the inventory of the inputs and outputs of the product's life cycle, for example the list of raw materials, gases, emissions and their flow within the analytical model. The third phase is the subdivision of the different inputs and outputs into impact categories. Impact categories are classes that represent environmental issues of concern for the LCA, for example global warming, resource depletion or land use. The impact potential is then calculated for each category. The final phase of this analysis is the interpretation of the results and the evaluation with the scope and goal that were set at the beginning of the analysis. The scope of the results' interpretation is to show the possible environmental improvement that one can derive by choosing one option rather than another.

The use of the LCA analysis is effective within a decision-making process when it is performed together with an economic assessment of the different alternatives and at the same time social concerns are taken into account. This process helps sustainable decision-making.

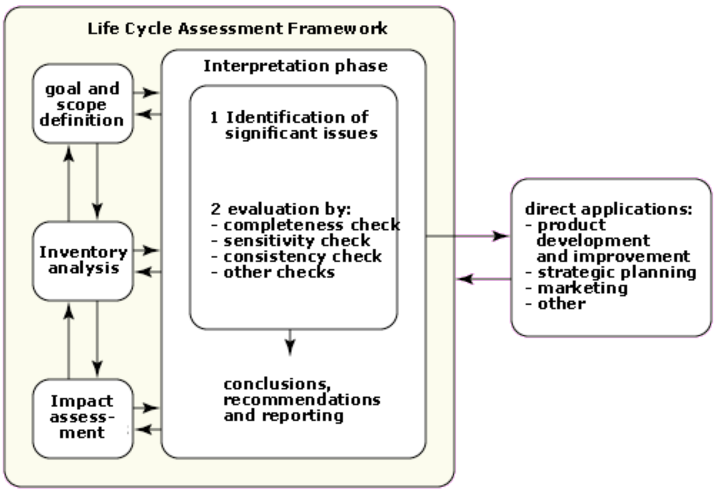


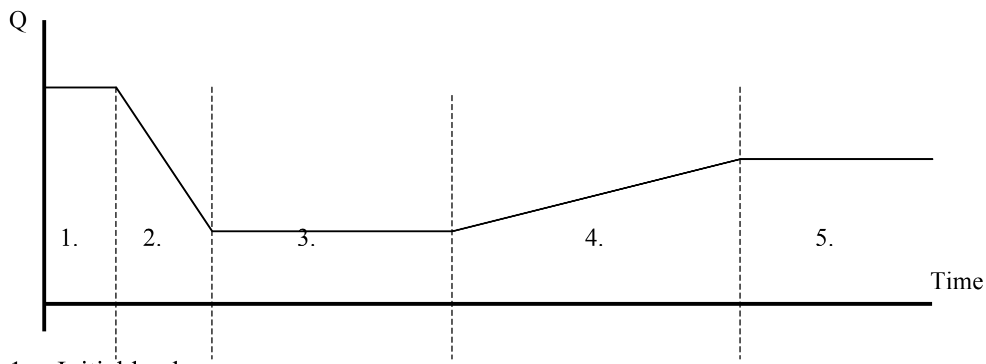
Fig. 1-1: Graphic representing the Life Cycle Assessment steps (http://awmc.uq.edu.au/images/projects/lca.gif).

1.3.2. Land use within the Life Cycle Analysis

The list of impact categories evaluated in the framework of LCA also includes land use. The production of goods and services for human purpose implies the use of a determinate land surface. This use can display different intensities depending on the method of production, the period of land occupation and also on the type of territory where the land is used. All these factors can increase or decrease the land use impact and also the influence that the human intervention has on the original environment.

In general land use implies a land transformation and causes a decrease in ecosystem quality resulting in erosion and changes in the soil components and fertility. These processes are strongly linked to changes in the species habitat.

All human activities affecting land can normally be divided into four phases: land transformation, land occupation, land restoration and land abandonment. During the land transformation a certain type of land cover is transformed into another type, this second one normally implies an anthropogenic land use activity with commercial purpose. The land occupation is the period of time where the anthropogenic land use activity takes place. The duration of this occupation also plays an important role while measuring the intensity of the land use impact. Land recovery is the phase after land occupation where the ecosystem recovers from the effects of the occupation. The recovery can be natural or supported by external help and the period of restoration is in general longer then the period of transformation. In certain cases after the first occupation the land is transformed again for the purpose of a second type of land use activity, slowing down or jeopardizing the land recovery process.



1. Initial land cover
2. Land transformation
3. Land occupation
4. Land recovering
5. Land abandonment

Q = Ecosystem quality

Fig. 1-2: The phases of land use activity and their impact on the ecosystem quality (Milà I Canals, 2006).

The transformation of land cover implies changes or even destruction of natural habitats causing a decrease in ecosystem quality and simultaneously the endangerment of species.

The function describing the total damage that a land use activity can generate is expressed in the area multiplied by the period of time of the land use and the characterization factor. The characterization factor symbolizes the biodiversity level on regional and local scale (Koellner, 2001).

$$Damage = Characterization\ factor * Area * Time \tag{1}$$

The characterization factor is calculated according to the equation (2):

$$ED = 1 - \frac{S_{landuse}}{S_{reference}} \tag{2}$$

where $S_{landuse}$ is the species number of the land use taken in consideration and $S_{reference}$ is the species number of the land use that has be chosen as a reference. Normally this reference state corresponds to the primordial land cover, where the anthropogenic activities did not influence the environment.

1.3.3. Biodiversity within LCA

In the previous paragraph the importance of biodiversity for the ecosystem properties and consequently for the humankind was emphasized. Land use is a human activity that direct affects the biodiversity level. A land use activity can act positively and provide an enrichment of the biodiversity level of a region or, as in most cases, act negatively and cause the loss of species. For these reasons it is important to assess also the impact of land use within the framework of LCA.

Former studies aimed at developing a method for the evaluation of the impact of land use on biodiversity. Koellner (2001) developed a method analyzing the number of vascular plant species in relation of distinct land uses in the region of Central Europe. The number of vascular plant species as a proxy for the taxonomic biodiversity was also used by Lindeijer (2000) who assessed the biodiversity and the life support function changes of ecosystems due to land use and Schmidt (2008) who proposed an assessment method analyzing the regions of Denmark and Malaysia on regards of vascular plants biodiversity.

1.3.4. The choice of the biodiversity indicator for the purpose of LCA

The definition of biodiversity can have different meanings depending on which aspect one decides to consider. The most popular definition of biodiversity is the number of species present in a determinate ecosystem or regions, called taxonomic biodiversity. However, from other points of view, biodiversity can also be interpreted as the alleles richness within a population (genetic diversity) or the number of different habitats that an ecosystem includes (ecosystem diversity) (UNEP, Convention on biological diversity, 1992). Another important aspect of the topic is the functional biodiversity, which is crucial if one looks at preserving the ecosystem integrity and stability. Functional diversity focuses on the function that a determinate species carries out in its ecosystem. If this species would die out and no other species could substitute its role within the complex natural interactions there would be an ecosystem failure.

In effect there are many possible indicators valid for measuring the level of biodiversity, but these are not always applicable at a global level: they are often only meaningful at regional or local levels. Another problem is the information availability: data needed for the application of many indicators is not available. Until now the methods developed for the assessment of biodiversity changes due to land use employ the number of vascular plant species as a biodiversity indicator. Vascular plant species are a good indicator for different reasons. First of all calculating the ecosystem diversity or the genetic diversity or the functional biodiversity for every land use type would be too complicated and difficult to apply within the Life Cycle Assessment model. The restriction to taxonomic biodiversity could be a good compromise. However this definition includes all species present in a determinate ecosystem, from microorganisms to plants and animals. An analysis of this extent would be too intensive to perform, as not all the organisms' groups are equally studied. Vascular plant species are fairly cataloged around the world, making them a good indicator for the LCA. Vascular plants represent the first level of the trophic chain and offer habitats for many other species, therefore their presence influences life within an ecosystem.

1.4. Land use and biodiversity in the tropical zone of Latin America

1.4.1. Terrestrial biodiversity distribution

Even though all the regions on Earth are important at biodiversity level, some areas are more relevant in term of biodiversity conservation. In effect species diversity is unequally divided on Earth, i.e. some regions house the largest part of all species, for example the tropical zones. Others have a lower level of diversity, like the artic and polar regions. Tropical forests cover less than 10% of the terrestrial land area but represent its largest biodiversity reservoir (Mayaux et al. 2005). In general the closer to the poles one is, the less biodiversity is present. Based on this fact biodiversity conservation can focus on certain areas, where the need of an intervention is more pressing. These regions are commonly known as hot spots and are very sensitive to anthropogenic changes. The criteria characterizing a hot spot are the high number of endemic species (the area must have more than 1500 species of endemic vascular plant species) and the loss of more than its 70 percent of its original habitat. Actually the global hot spots are 25 and contain the 44 percent of the world plants and the 35 percent of the terrestrial vertebrates. The majority of these areas are situated in the tropical biome (http://www.biodiversityhotspots.org).

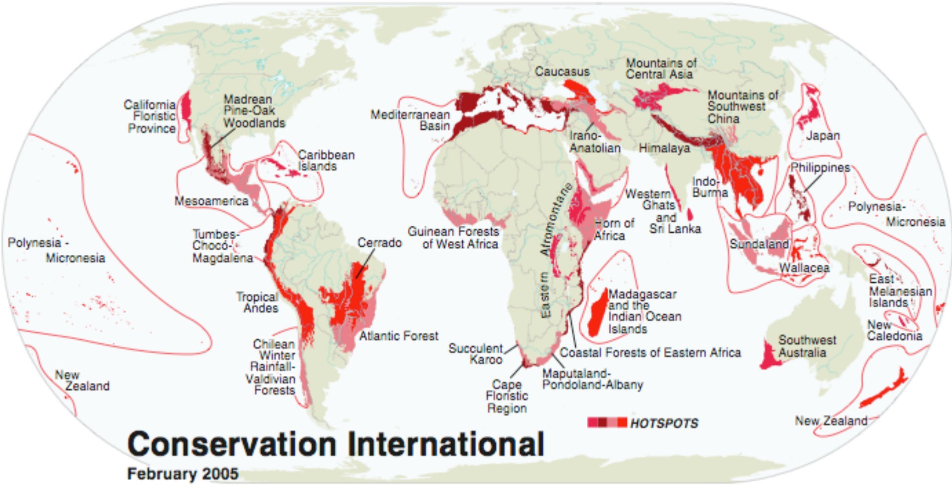


Fig. 1-3: Map of the biodiversity hot spots (Myers et al, 2000).

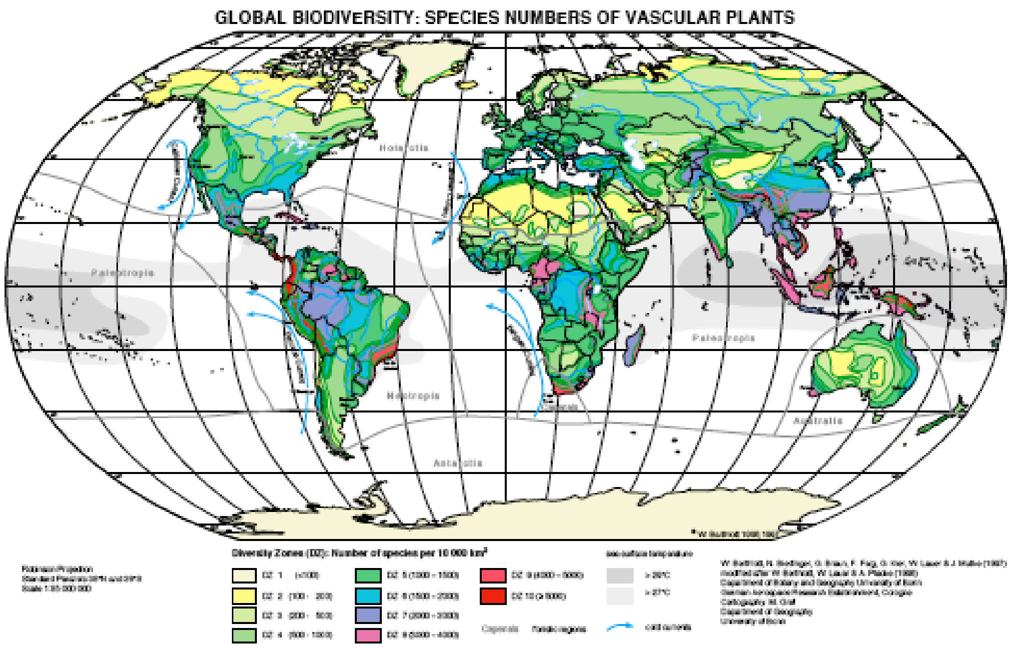


Fig. 1-4: World map illustrating the distribution of vascular plant species (Barthlott et al 1999).

1.4.2. The tropical region of Latin America as a biodiversity center

The tropical region extends from the tropic of Cancer in the Northern hemisphere to the tropic of Capricorn in the Southern hemisphere. This biome houses two-third of the global species but its also threaten by the biggest habitat loss.

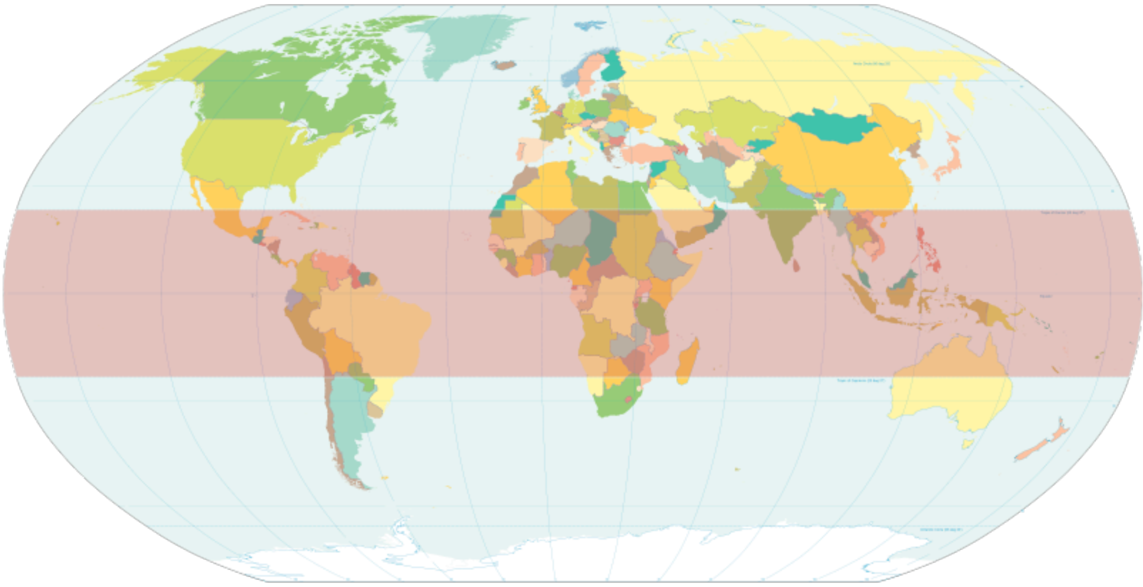


Fig. 1-5: Map of tropical biome (Gillespie et al, 1998).

The tropical region of Latin America includes the eight Central American countries, the Caribbean islands and 11 of the South American countries. This area contains seven of the global hot spots. One, the Mesoamerica region hot spots, covers almost all of Central America. In addition, according to Barthlott et al. (1999), this region also hosts two of the five vascular plant biodiversity centers: the Chocò-Costa Rica Center and the Atlantic Brazil Center. For these two reasons the tropical area of Latin America is a highlight if one aims at conserving the biodiversity and at mitigating the effects of the anthropogenic land use.

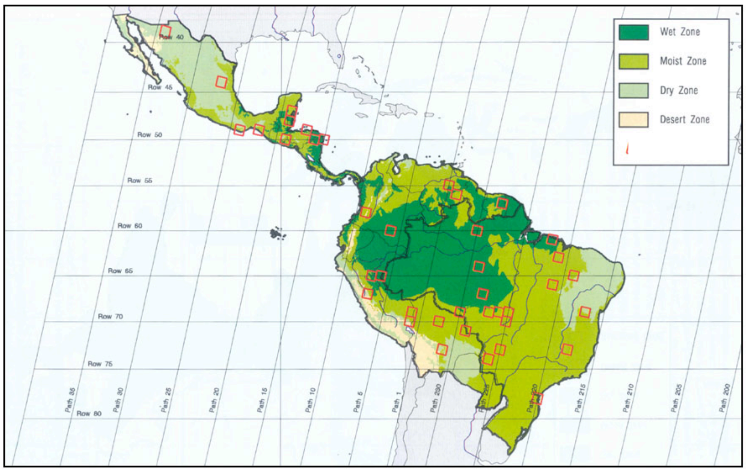


Fig. 1-6: Map showing the tropical region of Latin America divided into wet, moist, dry zones (www.fao.org/docrep/007/w0015e/W0015E96.jpg).

1.4.3. Land use in Latin America

The Latin American tropical region is of unique relevance regarding species conservation and biodiversity but it is also one of the regions that is most threatened by anthropogenic changes. The population in Latin America is growing at high rates and this also implies an increase in the demand of food, of resources and of territory needed for the building of infrastructures. These processes cause more and more natural land cover to be transformed or destroyed in order to supply the necessities of this demographic growth. As mentioned in the former paragraphs, land use is the main cause of the biodiversity loss happening in the tropical regions. In fact, land use causes the direct depletion of the habitat. At the present time tropical ecosystems are mainly destroyed for timber extraction, for the generation of pastureland and other agricultural purposes. All over the world agricultural land has doubled its surface in the last three decades, reaching 100 Millions of hectares (one quarter of the terrestrial surface). It has been calculated that by the year 2030 120 Million hectares in tropical countries will be committed to agriculture to sustain the food necessity of the population. In addition, the demand of alternatives to fossil fuels will encourage the bio-fuel production, enhancing deforestation in favor of crop fields in expectation of higher economical revenues. This depletion of natural land cover in favor of agriculture and pastureland does not only affect the surfaces occupied by tropical forest, but also mangroves and savannas have been overexploited dramatically for commercial purpose.

In Latin America the area occupied by natural land cover has been reduced drastically in the last decades. Deforestation has severe consequences on the biodiversity level; directly through habitat destruction and indirectly through habitat fragmentation. Because of the landscape's fragmentation into smaller parts, plant and animal populations are constrained into little fragments and genetic exchange between these is blocked. For this reason, individuals living in these forest blocks are more sensitive to changes (Gilpen and Oule 1986). Only in terms of vascular plant species 1'656 endemic plants from Mesoamerica are lost due to deforestation (Brooks 2002).

As mentioned above, pasture is the most land consuming human activity in Latin America. Humans are actually destroying a lot of natural environments for cattle production. The intensity of this activity can differ, depending on how many animals are grazing, how many times the grass is cut and to which extent herbicides are utilized. The major cause of deforestation in Latin America is neither timber extraction nor mining, but cattle pastures. In the same way the natural landscape has been transformed from agricultural development committing wide areas to intensive crop monocultures.

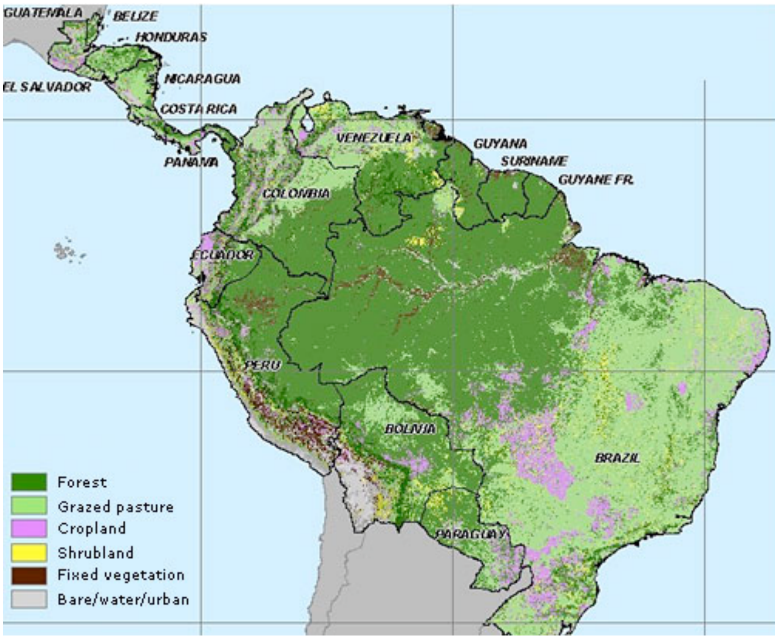


Fig. 1-7: Map showing the major land use activities concerning Latin America (www.fao.org).

According to "The Nature Conservancy" (2005) the main agricultural and pasture systems present in the Tropical region of Central America are:

- Large agro-industrial plantations (sugarcane, banana, African oil palm, citrus, pineapple and other fruits)
- Small and medium plantations of coffee and cocoa
- Medium and large plantations of fruits and vegetables which are integrated into market chains for processing and packaging
- Large industrial farms dedicated to the cultivation of basic grains (rice, maize and beans)
- Intensive production systems of chickens, pigs and dairy cattle
- Small farms dedicated to the production of basic grains, small livestock, vegetables for internal markets
- Large and medium extensive cattle producers

The agricultural systems listed above for Central America are also found in tropical countries of South America. In general there are typical trends in the land use activities across tropical regions. These activities act with different intensities on the various environmental components. For this reason it is important to analyze the different ways of production applied in the tropical countries, in order to offer decision-makers, non-governmental and governmental organizations the possibility of choosing the less environmental damaging alternative. Using the LCA method it is possible to perform this analysis and gather information on the environmental impact of goods and services. As mentioned in the paragraphs above one environmental impact that has to be taken into consideration is land use and the consequences that it implies, i.e. the biodiversity loss. In order to perform a complete LCA of the impact of land use on biodiversity It is necessary to gather information on species richness. This work aims to collect this information in the tropical region of Latin America.

1.5. Hypothesis

1. In previous studies (Koellner, 2001; Lindeijer, 2000; Schmidt 2008) has been demonstrated that the level of biodiversity tends at decreasing with the increment of intensity of the anthropogenic land use activity or with the increase of the human intervention. The hypothesis is that the natural environment of the tropical region of Latin America owns the higher level of vascular plants biodiversity and that this level decrease with the intensification of the human activities or the increment of the anthropogenic inputs, i.e. the use of chemicals, fertilizers, pesticides.

2. This work is based on the experts' evaluation on biodiversity and on the meta-analysis of published data. The second hypothesis claims that the experts' evaluation and the meta-analysis data on biodiversity follow a similar trend in respect the different land use activities.

3. The final step of this analysis is the creation of the EDP (Ecosystem Damage Potential) characterization factors for the Latin American tropical region. Each land use activity has an impact on the ecosystem, the EDP characterization factor is a measure that multiplied per area of land use and time of occupation can determine this impact. Koellner et al (2008) already have calculated the EDP characterization factors for the land use applied in Central Europe; this work aim to define the EDP for land use activities in Latin American tropical regions.

2. Materials and Methods

This work is divided into two parts. The first part is based on the analysis of existing data concerning the amount of trees and shrubs species in respect to different land usess in the tropical area of Latin America. The second part is a complementation of the first part. Initially, the objective of the meta-analysis was to collect data concerning all the vascular plant species. The availability of these data for the region analyzed was little, therefore I restricted my research on the vascular plant with d.h.b ≥ 10 cm. In order to complete the information on the plant biodiversity in the tropical region of Latin America I performed the second part of this work. This part is the gathering of expert knowledge on vascular plant biodiversity through an international expert survey concentrated on the tropical region of Latin America.

The first step which is necessary for carrying out these two analysis is the development of a land cover classification that meets the needs of LCA and can be furthermore used for the analysis of other continents and not just for Latin America.

2.1. Development of a new land cover classification

In order to perform an analysis on the impact of land use on the biodiversity it is important to complete a classification including all different land covers present on the earth surfaces to avoid the tag “unclassified land”. This system has to be applicable at a global scale to allow the comparison of similar products and services coming from different parts of the world.

There is a difference between the terms “land cover” and “land use”. De Gregorio et Jansen 2000 define land cover as “the observed (bio) physical cover on the earth’s surface, including the vegetation (natural or planted) and human constructions (buildings, road, etc.), which cover the earth’s surface. Land use is characterized by the arrangements, activities and inputs people undertake in a certain land cover type to produce, change or maintain it. Land use establishes a direct link between land cover and the actions of people in their environment.”

Different projects describe and classify the earth surface (Giri et al, 2005, Eva H. et al 2004). A complete description of the Earth’s land cover can be useful for different purposes and help the decision-making process, especially in environmental questions. Land cover classification is one of the key elements for the evaluation of changes on the Earth’s surface through the years or the estimation of the impact that a human intervention or a natural fact originates. The criteria for the development of a classification system are always specific for a determined purpose, for example focusing on the type of vegetative cover or on the climatic conditions. In other cases the classification systems are restricted to just a determinate continent (Bartholomé et al 2002, Fritz and See, 2005).

For the aim of this study the classification has to take into account different aspects: vegetation, artificial areas and physical conditions and has to be equally valid for all the continents. Therefore, the starting point for the assessment of the land use impact on biodiversity is the homogenous but at the same time precise classification of land cover present on the world. In this way the analysis can have a global utility. The second characteristic that the classification has to fulfill is the differentiation into the intensity levels with which the anthropogenic land use-changes take place. This second aspect of the classification is then useful for LCA purposes.

Following these provisions, a global and homogeneous nomenclature and the description of intensity of land use, the ideal classification will have two or three levels. In this case the third level of the classification will compile the inventory of the human activities and their intensity.

As mentioned before, several projects aimed already at describing the Earth surface, but no one of these classifications was fully appropriate for the scope of this study. Therefore, I developed a special classification for the project that performs the functions of global effectiveness and intensity's description. For this purpose, I created the classification focusing on the products of two projects, the Global Land Cover Classification 2000 and the CORINE Classification.

2.1.1. The Global Land Cover 2000 project

The Global Land Cover 2000 project consists of the collaboration between 30 research teams coming from all around the world and it is coordinated by the European Commission's Joint Research Center. The project aims to develop a new global land cover classification that can be useful for environmental organizations or programs, for policy makers, for the industries and governmental and non-governmental organizations (Bartholomé E. et Belward A.S. 2005).

In order to achieve a consistent product each continent is analyzed as a distinct region but following identical guidelines. In some cases continents are split into sub continents to maximize the precision of the description.

The Global Land Cover classification divides the earth surface into 18 regions. Fig 2-1 shows the location of the 18 regions. Experts map each region using the SPOT-4 VEGETATION VEGA2000 sensor. This vegetation sensor onboard the SPOT-4 satellite provides daily a global imagine of the different Earth regions. Using this method every research group disposes of the possibility of shooting with the same resolution (Pixel resolution at equator 1 km).

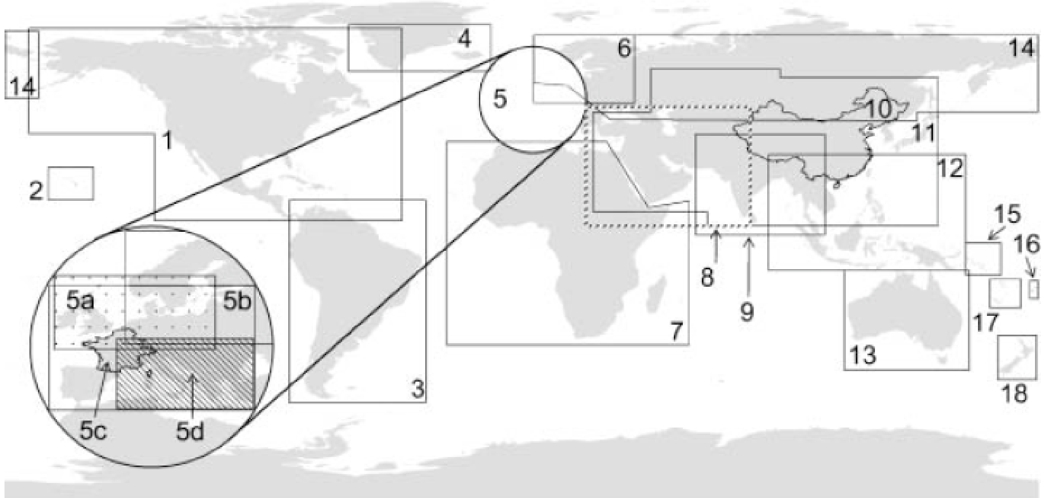


Fig. 2-1: Location of the 18 GLC 2000 studied regions (Bartholomé et al. 2005).

A common nomenclature is fundamental in order to homogenize the classification. This nomenclature has to allow the classification of all land cover found on the Earth surface. For this purpose the regional experts perform the mapping using the Land Cover Classification System (LCCS) software developed by FAO (Food and Agriculture Organization) and UNEP (United Nation Environmental Program). The LCCS supplies at the same time an uniform classification method, which still provides flexibility for the description of the land cover in the national and regional levels. These characteristics are relevant in order to compare similar land cover situated in different continents, (for example grassland in Europe compared with grassland in South America).

The LCCS is based on a two phases methods, the first is the dichotomous phase, which catalogues the land surface in eight classes following three criteria: the presence or the absence of vegetation, the quality of the edaphic substratum and the degree of artificiality. The second phase of the LCC system characterizes the eight main classes with the help of specific classifiers so as to allow a detailed labeling procedure. These classifiers are chosen in order to better describe the particularity of eight principal classes of land covers, for example the environmental attributes and the climate/geographic conditions. Although, not all of the classifiers have to be integrated in the development of the nomenclature, at the end is the number of classifiers used that influences the degree of precision of the tagging (de Gregorio and Jansen 1998, Atyeo and Thackway 2006). The form and characteristics of the surface define which classifiers have to be used for the description of a territory, example of classifiers are the type of vegetation present (broadleaved or needle-leaved) for a vegetative area or the type of crop (annual or semi-perennial, perennial crop) for an agriculture land. The GLC2000 project uses as principal classifiers density and height, for example the extent of the vegetative cover (closed or open). These classifiers height and density are also the thresholds set by the LCCS software for the development of a consistent legend.

The GLC2000 project database contains two sets of information: one is a detailed land-cover legend valid at continental or regional level, the other set is a less exhaustive legend applicable at global level. In the global legend all the 19 regional classifications were assembled into 22 main land cover categories, even though the more detailed regional legends vary between 5 and 44 land covers. The 22 land cover categories can be separated into 9 main groups as depicted in Tab. 2-1.

Tab 2-1:The Global Land Cover 2000 classification system illustrated on two levels with the respective land occupation (Bartholomé et al 2000).

1st Level	2nd Level	Land occupation (%)
Forest	• Tree cover, broadleaved, evergreen	8.38
	• Tree cover, broadleaved, deciduous, closed	4.44
	• Tree cover, broadleaved, deciduous, open	2.57
	• Tree cover, needle-leaved, evergreen	6.21
	• Tree cover, needle-leaved, deciduous	2.58
	• Tree cover, mixed leaf type	2.18
	• Mosaic: other tree cover vegetation	1.64
	• Tree cover, burnt	0.21
Shrublands	• Shrub cover, closed-open, evergreen	1.41
	• Shrub cover, closed-open, deciduous	7.72
Grassland	• Herbaceous cover, sparse shrub cover	9.00
	• Sparse Herbaceous cover, closed-open	9.37
Wetland	• Regularly flooded shrub and/or herbaceous cover	1.16
	• Tree cover, regularly flooded, fresh water	0.39
	• Tree cover, regularly flooded, saline water	0.08
Agriculture Areas	• Cultivated and managed areas	11.65
	• Mosaic: cropland/tree cover/other natural vegetation	2.39
	• Mosaic cropland/shrub and/or grass cover	2.11
Bare Areas	• Bare areas	13.52
Water Bodies	• Water bodies	1.73
Snow and Ice	• Snow and Ice	11.08
Artificial Areas	• Artificial surfaces and associated areas	0.19

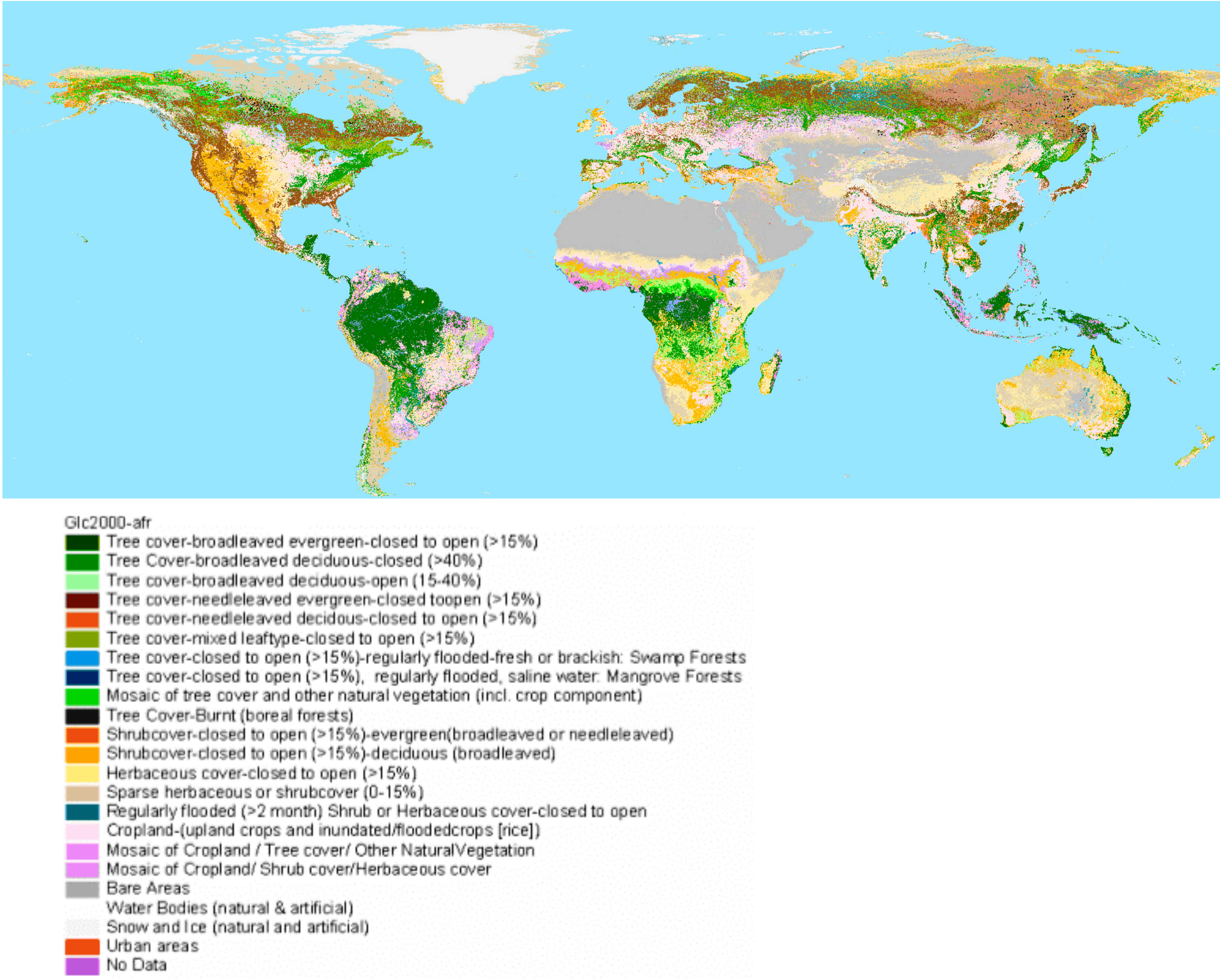


Fig. 2-2: World map according to the GLC2000 project (www.ier.jrc.cec.eu.int).

Thanks to this project, the whole world surface has been mapped and subdivided according to these 22 categories (definition of the 22 categories in Appendix1).

According to Fritz et al (2005) the continents are dominated by different land cover types, Oceania is dominated from the grasslands and shrub lands (70%), while the 40 % of Europe is covered by agriculture areas and just 15% is covered by grass and shrub lands. South America shows the greater forest coverage (45%) while one third of the African continent is occupied from barren or desert areas. According to this information the GLC2000 already illustrates the land cover difference between continents and regions.

2.1.2. The CORINE Land Cover Classification

The CORINE Land Cover Project (European Environmental Agency 2000) offers a detailed classification of the Europe's land cover. This project is supported by the European Community and is part of the CORINE program. The CORINE program aims to compile and organize the environmental information in order to facilitate the decision-making process within the environmental policy of the European Community. Thanks to this program the governmental and non-governmental organizations have a common reference for the examination of topics concerning environment and natural resources. The CORINE program gives the possibility to reproduce the information on regional, national or continental scale, therefore is a useful instrument for policy maker of national and international agencies but also for the policy makers of regional offices (CORINE land cover report, 1995).

CORINE classification system describes with the same accuracy artificial and natural surfaces. This is why every land cover type has an exhaustive description accompanied from a satellite shooting (scale chosen for the project is 1:100'000).

The main categories of the CORINE classification are artificial surfaces, agricultural surfaces, forest and semi-natural areas, wetlands and water bodies. The five categories are divided into 15 classes in the second level, and 33 subclasses in the third level.

CORINE is a practical classification system for the purpose of LCA because it has a precious advantage; it already describes the urban and industrial infrastructures according to different types of anthropogenic use. The same is valid also for the agricultural areas where the distinct types of cultivation methods are listed. For example the artificial surfaces category distinguishes between rails and roads or airports and railway stations and the built up areas are listed according to their level of intensity. The disadvantage of the CORINE classification is the fact that it takes in account just the European land cover therefore is too confined for a global use. Koellner et al 2007 elaborates a more detailed CORINE classification that matches better the requirements of the LCA. The proposed CORINE + system takes in account the distinct methods applied in the present agriculture and pasture, for example organic or integrated cultivation. The application of pesticides and the use of organic fertilizers have different impact on the environment, like monocultures and polycultures can influence the biodiversity in distinct manners. For this reason is important to distinguish the methods applied for the production of goods and services while developing the land cover classification.

2.1.3. Land cover classification for LCA purpose

The development of the new classification is based on the two classifications described above. The first level has to fulfill the criterion of global and homogeneous application. This criterion can be satisfied using the GLCC 2000 system. In second place the classification has to expose different levels of intensity, especially pertain to the territories whose environment is influenced by human activity. This second criterion can be fulfill from the CORINE + system. As explained before the CORINE + is developed for the European continent for this reason it can't be used directly for other continents, since the types of human activities can vary between regions worldwide.

The developed classification is structured into three levels. The first level reflects the 9 main categories of the GLCC2000. The second level lists the 22 land cover categories of this project. In this way is sure that every territory on the Earth's surface can be categorized following a common method. The third level which describes the distinct land use types comes in part from the third level of the CORINE + classification, especially regarding the definition of urban and industrial zones (see Appendix 2). The development of the third level for the forest, agriculture and grassland categories was the results of discussions with CATIE (Centro Agronomico Tropical de Investigacion y Enseñanza) researchers Dr. De Clerk, Dr. Somarriba, Mr. Tobar Lopez and Mr. Rios. The third level is designed for characteristics of the land use activities applied in Latin America especially for the agriculture and grassland categories, i.e. the cultivation of perennial crops with multiple shade strata. The flexibility of the third level is an important feature of this new classification system.

Not for all the land cover categories on the second level there is a third level. Categories were no vegetation is present or were the human intervention is little, are described only until the second level, since there are no relevant anthropogenic changes within these categories influencing the vegetation structure and the species composition.

The classification system developed for the LCA analysis, called GLC2000+ is illustrated on the Table 2-2. The description of every land cover types is displayed in the Appendix 2.

Tab. 2-2: The land cover classification system used for the analysis of the land use's impact on biodiversity for the purpose of Life Cycle Assessment.

First level	Second level	Third level
Forest	1. Tree cover, broadleaved evergreen, closed to open (>15%)	• Undisturbed mature forest • Mature forest • Secondary forest • Disturbed secondary forest • Early secondary growth • Plantation
	2. Tree Cover, broadleaved deciduous, closed (>40%)	• Undisturbed mature forest • Mature forest • Secondary forest • Disturbed secondary forest • Early secondary growth • Plantation
	3. Tree cover, broadleaved deciduous, open (15-40%)	• Undisturbed mature forest • Mature forest • Secondary forest • Disturbed secondary forest • Early secondary growth • Plantation
	4. Tree cover, needle-leaved evergreen, closed to open (>15%)	• Undisturbed mature forest • Mature forest • Secondary forest • Disturbed secondary forest • Early secondary growth • Plantation
	5. Tree cover, needle-leaved deciduous, closed to open (>15%)	• Undisturbed mature forest • Mature forest • Secondary forest • Disturbed secondary forest • Early secondary growth

First level	Second level	Third level
		• Plantation
	6. Tree cover, mixed leaf type, closed to open (>15%)	• Undisturbed mature forest • Mature forest • Secondary forest • Disturbed secondary forest • Early secondary growth • Plantation
	7. Mosaic of tree cover and other natural vegetation	
	8. Tree Cover, burnt (mainly boreal forests)	
Wetland	9. Tree cover, closed to open (>15%), regularly flooded, saline water: Mangrove Forests	
	10. Tree cover, closed to open (>15%), regularly flooded, fresh or brackish water: Swamp Forests	
	11. Regularly flooded (> 2 month) Shrub or Herbaceous cover	
Shrub land	12. Closed to open (>15%), evergreen(broadleaved or needle-leaved)	• Shrub land, no tree cover • Shrub land, with tree cover
	13. Closed to open (>15%), deciduous (broadleaved)	• Shrub land, no tree cover • Shrub land, with tree cover
	14. Sparse Herbaceous or sparse Shrub cover	
Grassland	15. Herbaceous cover, closed to open (>15%)	• Grassland, without tree cover, unused • Grassland, with tree cover, unused • Grassland, no tree cover, low impact use • Grassland, no tree cover, intense use • Grassland, low tree cover, low impact use • Grassland, low tree cover, intense use • Grassland, high tree cover, low impact use • Grassland, high tree cover, intense use • Grassland, sparse herbaceous cover, intense use
Agriculture	16. Cropland (upland crops or inundated/ flooded crops as e.g. rice)	• Annual crop, conventional • Annual crop, organic • Annual crop, flooded (e.g. rice) • Perennial crop, conventional • Perennial crop, organic
		• Annual crop, conventional,

First level	Second level	Third level
		shade tree cover • Annual crop, organic, shade cover • Perennial crop, conventional, shade tree cover • Perennial crop, organic, shade tree cover
	17. Mosaic of Cropland / Tree cover/ Other Natural Vegetation	• Annual crop, conventional, multi strata tree cover • Annual crop, organic, multi strata tree cover • Perennial crop, conventional, multi strata tree cover • Perennial crop, organic, multi strata tree cover
	18. Mosaic of Cropland / Shrub or Herbaceous cover	
Artificial Areas	19. Urban area(s)	• Road • Unpaved road • Rail • Urban, high intensity • Urban, medium intensity • Urban, low intensity • Urban green • Industrial, high intensity • Industrial, medium intensity • Industrial, low intensity • Extraction sites • Waste sites
Bare Area	20. Bare Areas	
Snow and Ice	21. Snow and Ice	

In the 22-land cover categories derived from the GLC 2000 classification system the areas covered with vegetation are tagged according to the kind of plants present. Thereof, forests with deciduous plants are distinguished from forests with evergreen vegetation, the same process happens for the shrub land categories. If one concentrates on one Earth region one can't expect to find all the land cover types listed in the classification system exposed in the table above. For example the tropical region of Latin America, the territory studied in this master thesis, does not host all the land cover types catalogued in the GLC2000+.

The structure into different levels permits to elaborate the analysis according to the dimension studied. For example if one decides to compare the environmental features of the forest taken as a whole category with the features of grassland only the first level of the classification is needed. On the other hand the accurate distinctions depicted in the third level of the classification systems are required if one decides to lists the environmental impact of different agricultural methods.

The structure of this land cover classification allows the deepening into more detailed description. In the third level more specification criteria can be added for an accurate analysis, depending on which aspect has to be evaluated. For example in the agricultural section one can further differentiate between irrigated or not irrigated crops, or between the amounts of chemical substances applied.

2.1.4. The Holdridge's life zones system used for the determination of the bio-climate

In order to distinguish which zones of the tropical region of Latin America are considered while carrying out the experimental parts of this thesis the Holdridge's life zones system was used. The method developed from Leslie Holdridge in 1947 is a global recognized schema for naming the Earth regions according to their bioclimatic conditions. The scheme is based on three coordinates that characterized a region: the annual precipitation, the annual biotemperature and the ration of annual potential evapotranspiration. According to these three criteria is possible to determine also the type of vegetation growing in a certain area. The Holdridge's life zones system is widely used in the scientific literature for the classification of the tropical and subtropical vegetation but it's also applicable to territories situated more northern or southern (L. R. Holdridge, Life Zone Ecology, 1967).

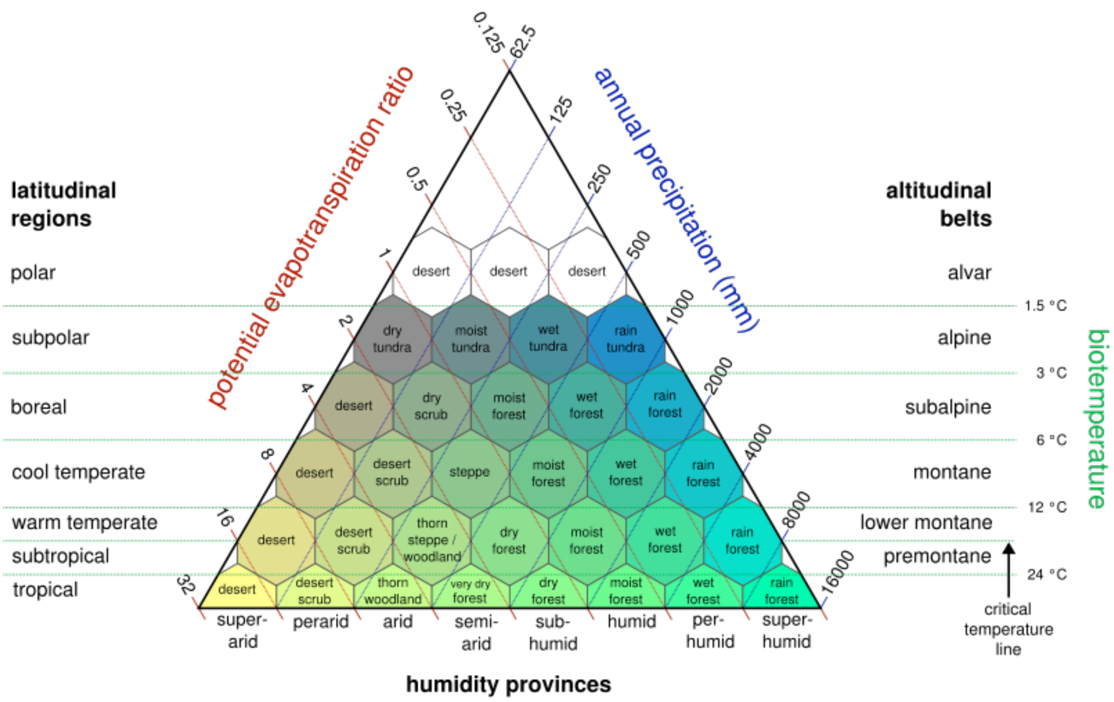


Fig 2-3: Characteristics of the Holdridge's life zones (Holdridge, 1947).

The broad application of this system in the tropical regions is the reason for its use for the subdivision of the Latin America area within this work. The evaluations of the experts were classified according to this system, following the bioclimatic conditions of their research area. In the same way were classified the data collected from the scientific publications and databases.

Another alternative could be the use of the WWF (World Wildlife Found) ecoregions. This Earth classification is based on a schema of eight biogeographic realms that are subsequently divided into more than 800 terrestrial, marine and freshwater ecoregions. Every ecosystem on Earth is described and ranked according to its biodiversity, environmental properties, climatic condition and habitat diversity. In the case of Latin America the number of ecoregions is elevate, for this reason the choice of using this Earth ranking would complicate the processes of data-collection and cataloguing of the results. For other Earth continents the choice of the ecoregions systems would be more appropriate.

The WWF website displays all ecoregions and their characteristics.
(http://www.panda.org/about_wwf/where_we_work/ecoregions/ecoregion_list/index.cfm)

2.2. Meta-analysis of published data

The first part of this study investigates the impact of land use on biodiversity through the meta-analysis of empirical data. The assessment is based on data coming from published articles appeared on journals pertaining to the ecology, agronomy, conservation and forestry fields. I analyze also master thesis, doctoral thesis or databases coming from the Orton library of the Tropical Agriculture and Higher Educational Center (CATIE).

2.2.1. The sources of the data

For the tropical region of Latin America the publication existing examine principally the number of species of plants with a d.p.h. of ≥ 10 cm present in an examination plots. D.h.p. signifies “diameter at breast height” and is taken at of 4.5 feet (1.37m) from the ground. It is one of the traditional measures used in the field of forestry, and represents a useful measure for the separation of trees, shrubs and herbal plants. It’s very rare to find publications that examine the total number of vascular plants in the tropical regions, because of their high number and density. For this reason the meta-analysis study is concentrated on the species diversity of plants with a d.p.h. of ≥ 10 cm and not on all the vascular plant biodiversity. For the evaluation the data are separated according to the Holdridge life zones and stem from publication concerning all the regions of Latin America, although the main part of the data concern the Central America area.

The land cover tags used in the publications not always correspond with the land cover labels listed in the classification on the Table 2-2. In order to compare the results of the meta-analysis with the results of the survey the empirical data are grouped following the GLC2000+ system. In this way the comparison of meta-analysis data and survey results will be easier to perform.

According to the Holdridge’s life zone given on the publications the data can be divided into tropical dry forest, tropical moist forest and tropical wet forest. Other data are collected for the pre-mountain and mountain life zones. However these data are not homogeneous and concern just a few number of land uses, whereupon the analysis's result would be inconsistent.

Tab. 2-3, 2-4 and 2-5 show the data sources and the land use types considered for the meta-analysis.

Tab. 2-3: Sources used for the data concerning the tropical wet forest, the land uses they are referring, the label used in the publication and the countries were the measurements took place.

Land use type	Data source	Description	Country
Primary forest	Mongue et al 1999	Primary forest	Costa Rica
	Lieberman et al 1985		Costa Rica
Secondary forest	Chacon 2003	Secondary forest	Costa Rica
	Guardia Vaca		Costa Rica
Disturbed Secondary forest	Lozada 2006	Disturbed Secondary forest	Ecuador
Riparian forest	Chacon 2003	Riparian forest	Costa Rica
Pasture high tree cover	Chacon 2003	Pasture high tree cover	Costa Rica
	Villacis et al 2003		Costa Rica
Pasture low tree cover	Villacis et al 2003	Pasture low tree cover	Costa Rica
	Chacon 2003		
Perennial crop, conventional, with multi strata shade trees	Lozada 2006	Coffee with shade trees	Ecuador

Tab. 2-4: Sources used for the data concerning the tropical moist forest, the land uses they are referring and the countries were the measurements took place.

Land use type	Data source	Description	Country
Primary forest	Trautman 2007	Primary forest	Honduras
	Oosterhoorn and Kappelle 2000		Costa Rica
	Stern et al 2002		Costa Rica
Secondary forest	Guiracho 2000	Secondary forest	Costa Rica
	Bonifaz Balseca 2004		Ecuador
	Soudre Zampano 2005		Costa Rica
	Oosterhoorn and Kappelle 2000		Costa Rica
	Diaz 2006		Nicaragua
	Enriquez Lenis et al 2007		Costa Rica
	Soudre Zampano 2005		Costa Rica

Land use type	Data source	Description	Country
Disturbed secondary forest	Soudre Zampano 2005	Disturbed secondary forest	Costa Rica
	Mongue et al 1999		Costa Rica
	Evans 2006		Guatemala
	Trautman 2007		Honduras
	Posada et al 2000		Colombia
	Stern et al 2004		Costa Rica
Early secondary growth	Enriquez Lenis et al 2007	Charrales	Costa Rica
	Reitsma et al 2001	Charrales	Costa Rica
Riparian forest	Enriquez Lenis et al 2007	Riparian forest	Costa Rica
Plantation	Enriquez Lenis et al 2007	Plantation	Costa Rica
Pasture high tree cover	Zamora et al 2001	Pasture high tree cover	Nicaragua
	Trautman 2007		Honduras
	Esquivel Sheik 2005		Nicaragua
	Oosterhoorn and Kappelle 2000		Costa Rica
	Stern et al 2003		Costa Rica
	Posada et al 2000		Colombia
	Cerrud et al 2004		Panama
Pasture low tree cover	Esquivel Sheik 2005	Pasture low tree cover	Nicaragua
	Enriquez Lenis et al 2007		Costa Rica
	Alcazar 2007		Costa Rica
	Oosterhoorn and Kappelle 2000		Costa Rica
Pasture with no tree cover	Enriquez Lenis et al 2007	Pasture with no tree cover	Costa Rica
Annual crop, conventional, with shade trees	Enriquez Lenis et al 2007	Monoculture, annual crop, with fruit trees	Costa Rica
Annual crop, conventional	Enriquez Lenis et al 2007	Monoculture, annual crop	Costa Rica
Perennial crop, conventional, with multi strata shade trees	Guiracho 2000	Cacao with shade tree	Costa Rica
	Enriquez Lenis et al 2007	Orchard	Costa Rica
Perennial crop, conventional, with shade	Reitsma et al 2001	Cacao with shade	Costa Rica
	CATIE database	Shaded coffee	Costa Rica
	Guiracho 2000	Banana with shade trees	Costa Rica

Tab. 2-5: Description of the sources used for the data concerning the tropical dry forest, the land uses they are referring and the countries were the measurements took place.

Land use type	Data source	Description	Country
Primary Forest	Gillespie et al 2000	Primary forest	Nicaragua
	Gentry et al 1995	Primary forest	Costa Rica Colombia, Venezuela, Ecuador, Peru, Bolivia
	Dodson and Gentry 1992	Primary forest	Ecuador
	Keel et al 1993	Primary forest	Paraguay
	Mongue et al 1999	Primary forest	Costa Rica
	Correa do Carmo	Primary forest	Nicaragua
	Lozada 2006	Primary forest	Ecuador
Secondary Forest	Sanchez et al 2005	Secondary forest	Costa Rica
Disturbed secondary forest	Lozada 2006	Disturbed secondary forest	Ecuador
Early secondary growth	Correa do Carmo 2000	Charrales	Nicaragua
	Sanchez et al 2005	Charrales	Costa Rica
Riparian Forest	Sanchez et al 2005	Riparian forest	Costa Rica
Pasture with high tree cover	Sanchez et al 2005	Pasture with high tree cover	Costa Rica
	Esquivel et al 2003		Costa Rica
	Guevara and Laborde 1993		Mexico
	Sanchez et al 2005		Nicaragua
	Arnaiz et al 1999		Nicaragua
	Correa do Carmo 2000		Nicaragua
Pasture with low tree cover	Correa do Carmo 2000	Pasture with low tree cover	Nicaragua
	Sanchez et al 2005		Costa Rica
Mosaic perennial crops and forest	Lozada 2006	Traditional coffee	Ecuador
	Perfecto et al 2003	Agroforestry	Mexico
	Correa do Carmo	Forest and coffee	Nicaragua
Perennial crop, organic, with multi strata shade trees	Philpott et al 2006	Traditional shaded coffee, organic	Mexico
Perennial crop, conventional, with multi strata shade trees	Soto Pinto et al 2000	Shaded coffee	Mexico
	Perfecto et al 2003	Shaded coffee	Mexico

Land use type	Data source	Description	Country
Perennial crop, organic, with shade trees	Philpott et al 2006	Commercial shade coffee, organic	Mexico
Perennial crop, conventional, with shade trees	Perfecto et al 2003	Shaded coffee	Mexico
	Philpott et al 2006		Mexico
Perennial crop, conventional	Philpott et al 2006	Sun coffee	Mexico

Empirical data concerning every land use types included in the GLC2000+ are difficult to find, especially the artificial areas show a lack of publications. In this work are mainly analyzed land uses belonging to the categories forest, grassland and agriculture, since in the Latin American tropical regions the biodiversity research is performed in majority in these three fields. Nonetheless also in the forest, grassland and agriculture sector it was difficult to gather data for all types of land use. The amount of publications concerning the different types of annual crop cultivation is scarce and frequently they don't make differences between the agricultural methods applied. In general the data concern more the different types of forest. The publications concerning grassland land covers study the amount of trees present on pasture area rather than the use of herbicides or pesticides.

The main part of the empirical data stem from the region of Central America, for this reason the agricultural areas data concern mainly coffee, cacao and banana plantations, since these are the most widespread crops.

Some empirical data pertaining to the herbaceous or shrub species are collected, however these data are insufficient to perform a meta-analysis, therefore are treated separately.

2.2.2. Standardization of the data

The empirical data are analyzed according to the method developed by Koellner (2001). This method based on the meta-analysis is developed for the evaluation of land use impact on vascular plants biodiversity in the region of Central Europe. The analytical process is adapted in order to reflect the requirement of the case studied in this work. First of all the analysis is conducted on a restricted group of species, instead of all vascular plants species only the plant species with d.p.h. ≥ 10 cm are taken in account, in the second place the land cover classification used for the evaluation is not the CORINE + but the GLC2000+.

According to scientific studies there are two main mechanisms that cause the increase of species amount, one is the increase of area the other is the increase of habitats. These two mechanisms are also bound together because an increase in area means the possibility of more habitats to be found (Triantis et al 2003; Harner R.F. and Harper K.T. 1976; Kohn D.D. 1985). Following the theory of Arrhenius (1921) the species number and the area size of a region are correlated through this function:

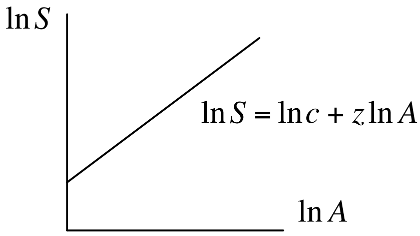
$$S = cA^z \qquad (1)$$

were S is the number of species, A the area's size, c the measure for species richness and z a measure for species accumulation rate.

By using the logarithm function on both sides of function (1) one obtains the following linear equation:

$$\ln S = \ln c + z \ln A \qquad (2)$$

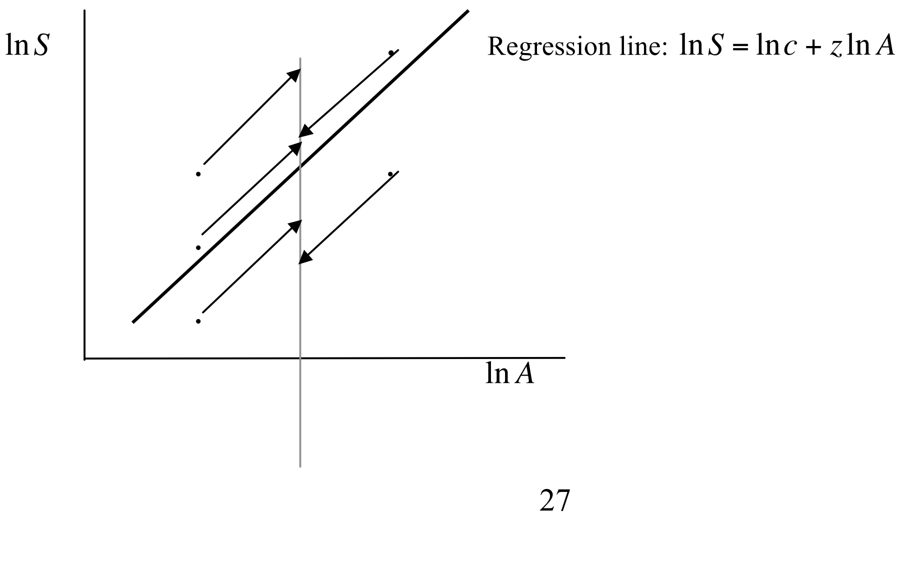
According to Koellner (2001) the equation (2) is considered the best function for modeling the species-area relationship and it is used within the method applied for the standardization of the data.



The value ln*c* represents the number of species present on the area's size =1and the slope of the function (here the value z) indicates the species accumulation rate. The parameter z increases for ecosystems with high level of species diversity.

The areas of the collected empirical data differ in term of size, for this reason is not possible to directly compare the species richness of different land use types.

The equation (2) is used to standardize the species number for all types of land use. Using the software Microsoft Excel the regression line is calculated for the data collected. All forest types, pasture areas and crop cultivations referring to the same Holdridge's life zone are plotted in the graph, expecting a higher species number with the increase of the area's size. The y-intercept of the regression equation corresponds to the species number for a unit area, in this case 1 hectare (ln1 = 0). The species numbers correspondent to 1 unit of $A_{standard}$ ($A_{standard}$ = 1 hectare) is calculated for all the data. One expects to have different richness of plant species in 1 hectare of land depending on which type of land use activity is applied.



Knowing the value A and the respective value S for each data point as well as the parameter z from the regression line one can find the value ln c for every point. The value ln c represents the number of species present in one hectare of territory for the different land use types.

The plant species richness per 1 hectare is calculated for every collected data of the three Holdridge's life zones taken in consideration. The data are then grouped in respect to the land use activity. The standard deviation is measured according to equation (3):

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{n}(x_i - \bar{x})} \qquad (3)$$

where N corresponds to the number of samples and x are the variable taken from $x_1 \ldots x_n$.

Also the standard error:

$$SE = \frac{\sigma}{\sqrt{n}} \qquad (4)$$

the maximal value, the minimal value and the median are calculated for every land use type.

In order to know if the bioclimatic conditions that characterize the Holdridge life zones affect the richness of plant species with d.h.b. ≥ 10 cm an ANOVA test of variance and a Bonferoni's Post Hoc test are performed with the program SPSS 16. With these two tests it is possible to compare the results obtained for the same land use types between the three life zones. For example one can test if there is a significant biodiversity's difference between tropical dry, moist or wet forest in one hectare of pasture with high tree covers. For this comparison it's necessary to look at the *F*-value of the ANOVA test. The *F*-value is a measure of the ratio of systematic variation to unsystematic variation.

$$F = \frac{MS_M}{MS_R} \qquad (5)$$

with MS_M = model mean squares model and MS_R = residual mean squares.

2.3. Experts' survey

The second part of the analysis on the impact of land use is an international experts' survey. The aim of the survey is to gather knowledge on the biodiversity level of distinct land covers types. The survey focuses also on the tropical region of Latin America and completes the results of the meta-analysis part.

2.3.1. The survey's structure

The GLC2000+ system restricted to the Latin American territory is used for the development of the questionnaire. The GLC2000+ allows a worldwide utilization, for this reason is possible that just a part of the land covers listed are present in the area taken in consideration in the framework of a project (in this study Latin America area). In order to allow a quicker and practical utilization of the questionnaire further specification of forest and shrub land cover into vegetation types (as depicted in the second level of GLC2000+ system) are omitted. Consequently the land cover legend insert in the questionnaire is simpler and composed just of two levels: the first level is the unification of the first and the second level of the GLC2000+ system, the second corresponds to the third level of GLC2000+ and shows the distinct land use activities with different degree of intensity (the legend used for the survey is illustrated in the Tab 2-3).

Tab. 2-6: Land cover legend used in the survey's questionnaire (the definition of every land use is shown in Appendix 2)

Level 1	**Level 2**
Forest	Primary forest, undisturbed
	Mature forest
	Secondary forest
	Disturbed secondary forest
	Early secondary growth
	Plantation
Wetland	Tree cover, regularly flooded, fresh water
	Tree cover, regularly flooded, saline water
	Regularly flooded shrub/herbaceous cover
Shrublands	Shrub cover, closed-open, no tree cover
	Shrub cover, closed-open, tree cover
	Sparse shrub/herbaceous cover
Grassland	Unused without tree cover
	Unused with natural tree/shrub cover
Pasture	No tree cover, low impact use
	No tree cover, intensive use
	Low tree cover, low impact use
	Low tree cover, intensive use
	High tree cover, low impact use
	High tree cover, intensive use
	Degraded pasture
Agriculture	Perennial or semi-perennial, conventional
	Perennial or semi-perennial, organic
	Annual, conventional
	Annual, organic
	Annual, flooded
	Annual, conventional with one stratum tree cover
	Annual, organic with one stratum tree cover
	Annual, conventional, multi strata tree cover
	Annual, organic, multi strata tree cover
	Perennial or semi-perennial culture, conventional, with one stratum tree cover
	Perennial or semi-perennial, organic, with one stratum tree cover
	Perennial or semi-perennial, conventional, multi strata tree cover
	Perennial or semi-perennial, organic, multi strata tree cover

Level 1	Level 2
Artificial	Paved road
	Unpaved road
	Rail
Urban	Urban, high density
	Urban, medium density
	Urban, low density
	Urban green areas
Industrial	Industrial, high density
	Industrial, medium density
	Industrial, low density
	Waste dump
	Extraction site

In order to collect the information regarding the vegetation type and at the same time to subdivide the evaluations the experts have to indicate the Holdridge life zone used as a reference for the compiling of the survey. The experts have the possibility to insert more than one life zone if they retain that the evaluation holds for more than one Holdridge's life zones.

The questionnaire is divided into two main questions: the first one direct analyzes the degrees of biodiversity that characterize different land use activities, the second one concerns the possible maximization of productivity and conservation within a delimited territory.
The survey includes also a second set of questions concerning methodological issues, in order to improve the questionnaire and to have a better interpretation of the results and a third set including questions regarding research activities of the expert.

The first question of the survey is directly oriented to the aim of characterizing the biodiversity level of the land use types, therefore the results can be used for the purpose of LCA. The richness of vascular plant species in one hectare is used as an indicator for the whole biodiversity situated in each of the land uses listed in the second level of the legend of the Tab. 2-2. Vascular plant species as a biodiversity indicator in the framework of LCA have already been used in other studies (Koellner 2001; Lindeijer 2000) and represent a practical solution for the evaluation of the whole diversity, for these reasons are used as a biodiversity proxy also in this analysis.

Every expert has to evaluate the level of vascular plant biodiversity present in the land use types of the region where he carries out his work. The evaluation has to be a value from 0 to 10, with 0 representing the minor level of vascular plant biodiversity and 10 corresponding to the major level. As an option the experts could enter the mean number of vascular plant species that they expect in one hectare of a determinate land use and estimate the maximal and minimal species number that one can finds. In the second question the experts have to enter the combination of three land use activities that according to their judgment would improve at the same time the biodiversity conservation and the productivity of a delimited territory.

The second part of the questionnaire queries the pertinence of the use of vascular plants species as a biodiversity indicator and the efficiency of the land cover classification used for the

survey. As mentioned before vascular plant species have also been used before as a representative for the whole biodiversity and is interesting to collect the opinion of experts on this choice.
The complete version of the questionnaire in English is illustrated in Appendix 3 (there is also a Spanish version of the questionnaire, not displayed in this work).

2.3.2. The distribution of the experts

The initial experts' list included 170 experts, but at the end the list counted 183 experts. Other 13 contacts were suggested from some of the 170 experts of the initial list. I chose the experts according to publications concerning biodiversity in agricultural landscapes or conservation of forests and natural areas in the tropical regions of Latin America. I consulted also the websites of organizations focusing on conservation issue or websites of botanic or agronomy institutes from universities situated in the regions of interest. Some of the expert's names were suggested from researchers of the Tropical Agriculture and Higher Educational Center of Costa Rica (CATIE). The experts are divided according to their research fields, in order to have equal represents for agriculture and pasture, forestry, systematic/botanic and conservation/ecology. Tab 2-4 shows the number of experts divided per research area.

Tab. 2-7: List with the four main research fields following which I chose the experts for the survey. Agriculture and pasture field includes researcher from agriculture and agronomy institutions, forestry field assembles researchers from forestry institutions, systematic and botanic concerns researchers working in botanical gardens or botanic institutes of universities and conservation and ecology includes researchers working in organization for nature conservation or ecology institutes of universities.

Research area	**Number of experts**
Agriculture and pasture	61
Forestry	56
Systematic/botanic	26
Conservation/ecology	39

2.3.3. The statistical analysis of the results

The results of the survey are separated according to the life zone(s) used as a reference for the filling out of the questionnaire and they are analyzed following this ranking system. The statistical analysis is performed using the software Microsoft Excel 11.3.7 for the calculation of the relevant values and for the representation of the graphs.

For the performing of the analysis of variance (ANOVA) between the experts' evaluations from the different life zones and for the Bonferoni Post Hoc test is used the SPSS 16.0 program. Through these tests one certifies the similarity of expert's evaluations between different life zones.

2.4. Comparison between survey's results and meta-analysis data

The second hypothesis of this work sustains that the experts' evaluations and the meta-analysis results follow a similar trend concerning the biodiversity level of diverse land use types. In order to prove this statement the two data sets have to be compared.

2.4.1. Transformation of meta-analysis data on a scale 0 to 10

The next step of the analysis is to compare the data collected through the experts' survey and the values obtained with the meta-analysis. First of all one has to remarks that the data derived from the publications concern the richness of vascular plant species with a d.h.b. of ≥ 10 cm whereas the answers of the experts are turned to the diversity of whole vascular plant species for each land use type.

The first step is to convert the value of the meta-analysis's results on a scale from 0 to 10 like the experts' judgments. The meta-analysis data are absolute values and correspond to the number of plant species found on each research plot. For the transformation of these data the value 10 is set to the highest number of plant species per hectare found and the rest of the data are transformed following equation 6:

$$V_S = \frac{S_H}{10} * S_S \tag{6}$$

where V_S is the biodiversity value (0-10) of a sample, S_H is the highest species number per hectare in the respective Holdridge's life zone and S_S corresponds to the specie number of the sample taken in consideration.

2.4.2. Statistical comparison

In order to compare the two data sets a Mann-Whitney test is performed for each Holdridge's life zone. The Mann-Whitney tests the differences between two conditions when different samples have been used in each condition. This test is based on the U value calculated following equation 7:

$$U = N_1 N_2 + \frac{N_1(N_1+1)}{2} - R_1 \tag{7}$$

where N_1 and N_2 are the sample sizes of groups 1 and 2 and R_1 is the sum of ranks for group 1.
A repeated-measures ANOVA is performed to compare the results of a land use type in comparison with the results of the other land use types.
The SPSS 16 program is used for the Mann-Whitney and repeated-measures ANOVA.

2.5. The calculation of the EDP

The final step of this analysis is the creation of the EDP (Ecosystem Damage Potential) characterization factors for the Latin American tropical region. As mentioned in the introduction the EDP is calculated as follow:

$$EDP = 1 - \frac{S_{landuse}}{S_{reference}} \tag{8}$$

with $S_{landuse}$ corresponding to the species of the land use analyzed and $S_{reference}$ corresponding to the number of species of the natural land cover. The natural land cover is the land cover that would be present without any human intervention, in the case of Latin American tropical the primary forest.

3. Results

3.1. Meta-analysis

As mentioned in Chapter 2 I performed the meta-analysis on data concerning the Holdridge's life zones tropical wet forest, tropical moist forest and tropical dry forest. For the other life zones that are present in Latin America not enough data were available to start the following analysis. I didn't perform the analysis for the absolute number of vascular plant species but only for the number of species of the plants showing a d.h.b of ≥ 10cm.

3.1.1. Calculation of the regression line

In order to derive the number of plant species for a fixed area I calculated the regression line of the local plots together with the regional plots. In the calculation are included the samples of all types of land use activities. The local plots show the number of plant species in respect to different land use types. The regional plots show the results for a greater area including more than one type of land use activity and in this way measure the landscape biodiversity.

The functions for the three Holdridge's life zones analyzed are:

for the tropical wet forest: $\ln S = 0.57 \ln A + 3.40$, A in ha; $R^2 = 0.23$

for the tropical moist forest: $\ln S = 0.39 \ln A + 2.93$, A in ha; $R^2 = 0.21$

for the tropical dry forest: $\ln S = 0.25 \ln A + 3.03$, A in ha; $R^2 = 0.24$

Fig. 3-1, Fig. 3-2, Fig. 3-3 show the graphs used to calculate the regression line for the three life zones analyzed. The samples are plotted ln *A* against ln *S,* with *A* measured in ha and *S* referring to the number of species of plants with a d.h.b ≥ 10 cm.

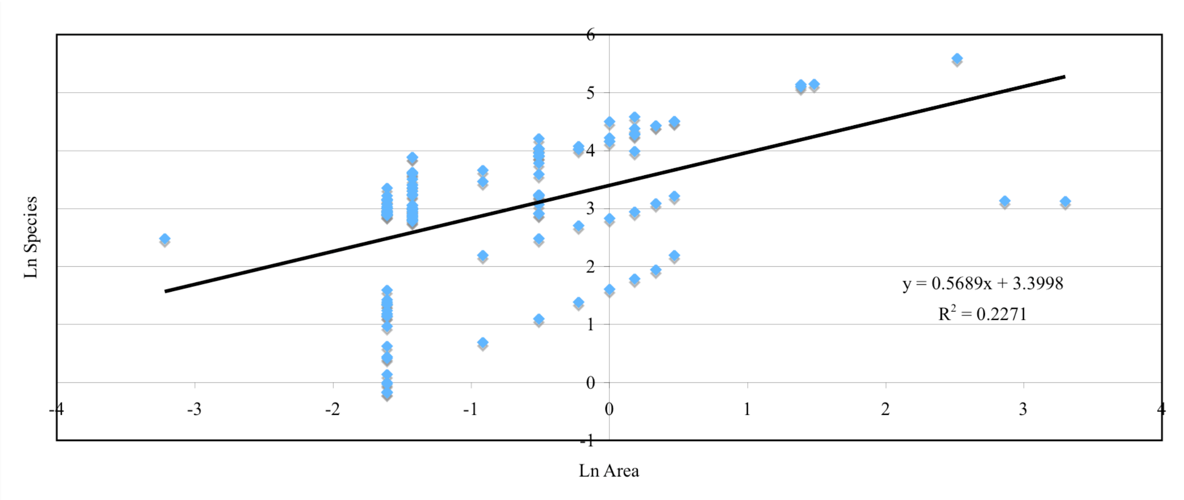


Fig. 3-1: Regression line of the local and regional plots concerning the tropical wet forest. The regression line (ln S = 0.57 ln A + 3.40) is calculated with A in ha and S equaling the number of species found in each plot.

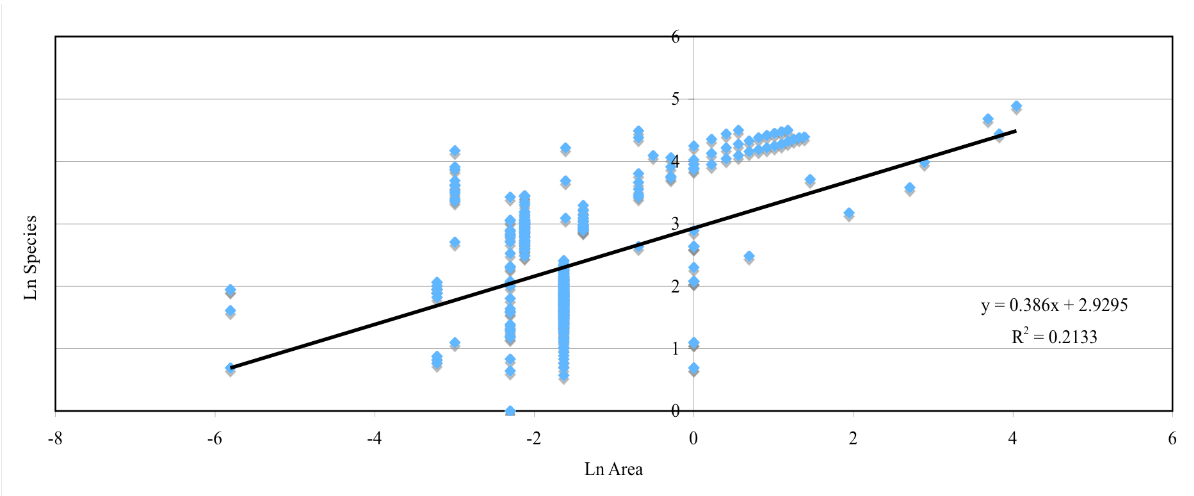


Fig. 3-2: Regression line of local and regional plots concerning the tropical moist forest. The regression line (ln S = 0.39 ln A +2.93) is calculated with A in ha and S equaling the number of species found in each plot.

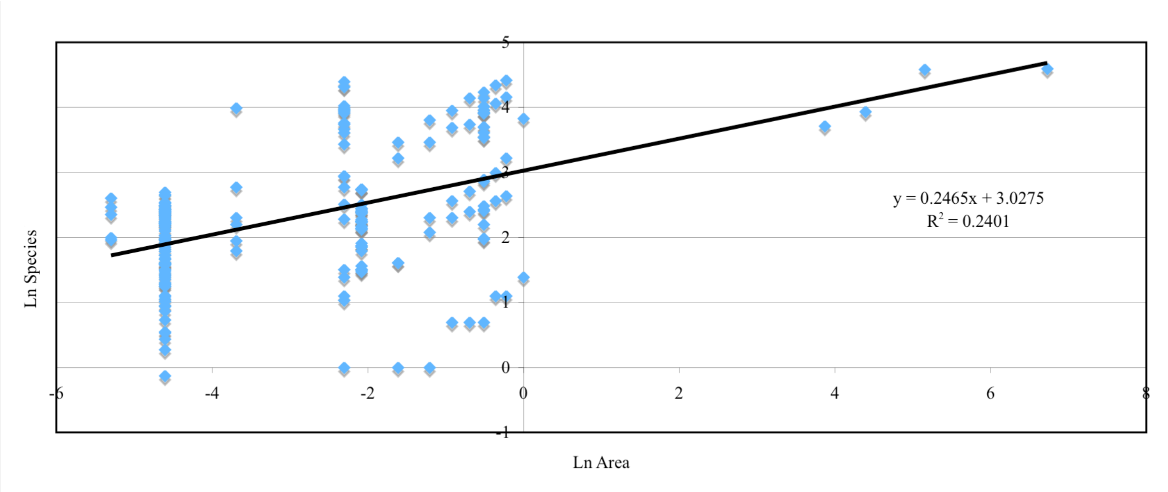


Fig. 3-3: Regression line of the local and regional plots concerning the tropical dry forest. The regression line (ln S = 0.25 ln A + 3.03) is calculated with A in ha and S equaling the number of species found in each plot.

3.1.2. The standardization of the species number

For the comparison of different land use types it is necessary to calculate the standardized species number for a fixed area. In this case I chose to standardize the species number for 1 ha ($A_{standard}$). To calculate the species equivalent in one hectare of the different land use types in the three Holdridge's life zones I used the method described in chapter 2.2.

Tab. 3-1, 3-2 and 3-3 represent the species' average for one hectare of the different land use types, the standard deviation, the standard error, maximal and minimal species number for each land use type and the number of samples analyzed. Fig. 3-4, 3-5 and 3-6 show the boxplots for the three Holdridge's life zones, while Fig. 3-7, 3-8 and 3-9 show the graphic representation of the means for each land use type and the respective standard error bar. The three Holdridge's life zones are represented with different land use types, since the data availability was not the same for each region.

Tab. 3-1: Mean of the standardized species number S for different types of land use concerning the tropical wet forest. The standardized species number S refers to the $A_{standard}$ = 1 ha.

Land use	Mean	St Dev	St Error	Max	Min	Median	Count
Primary Forest	77	7.91	3.23	90	67	77	6
Secondary Forest	56	17.89	2.64	107	36	48	46
Disturbed Secondary Forest	32	8.11	3.07	48	24	33	7
Riparian Forest	61	7.77	1.94	70	49	63	16
Pasture with High Tree cover	13	4.32	1.08	19	8	11	16
Pasture with Low Tree cover	4	1.51	0.37	7	2	4	17
Perennial crop, conventional, with multistrata shade	73	8.11	3.07	89	65	74	7

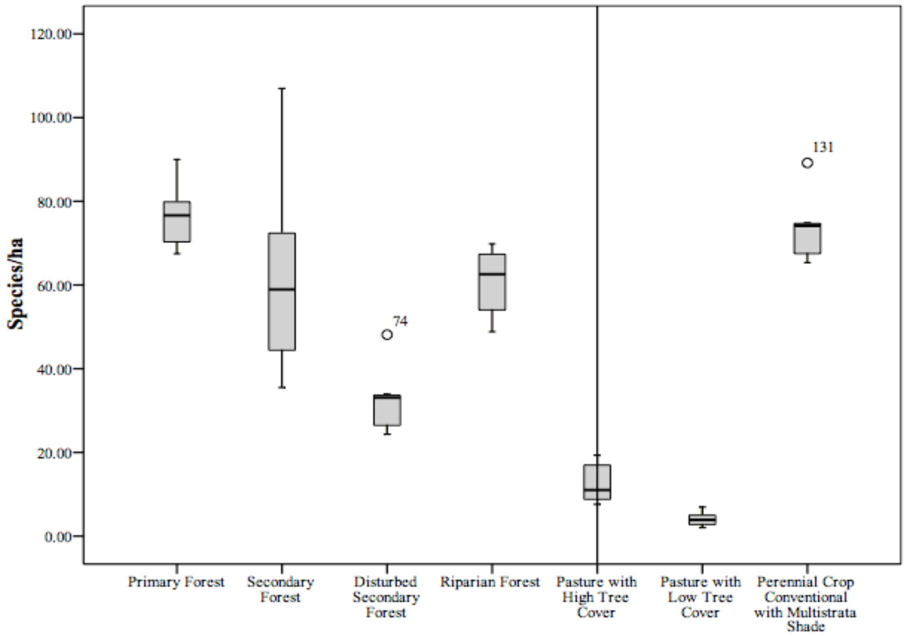


Fig. 3-4: Boxplots of the species per hectare of seven land use types calculated for the tropical wet forest area.

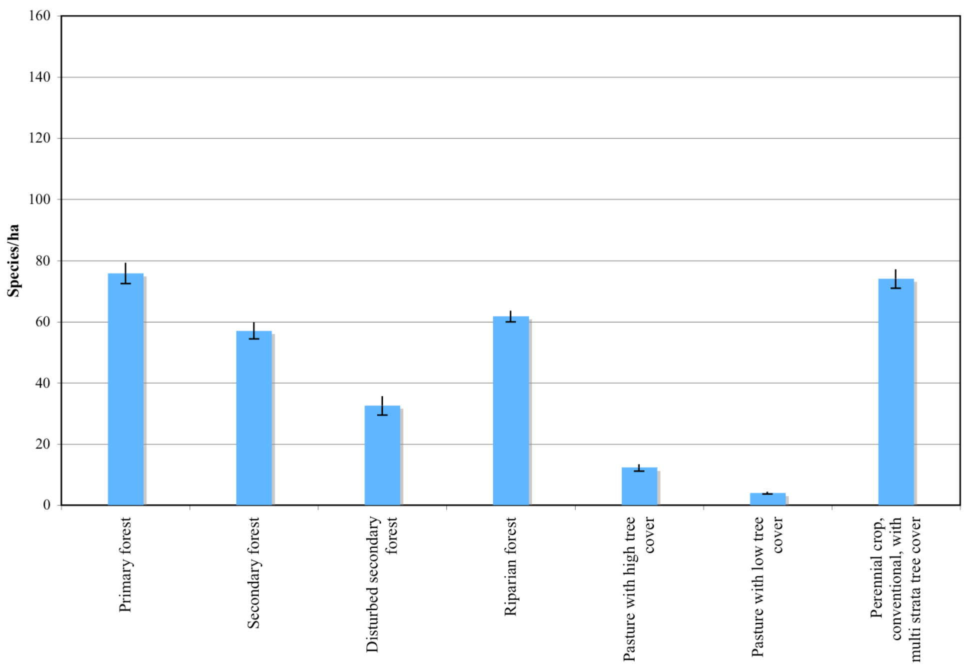


Fig. 3-5: The means of plant species (d.h.b ≥ 10cm) per hectare of seven different types of land cover in the tropical wet forest area (+/- standard error).

Tab. 3-2: Mean of the standardized species number S for different types of land use concerning the tropical moist forest. The standardized species number S refers to the $A_{standard}$ = 1 ha.

Land use	**Mean**	**St Dev**	**St Error**	**Max**	**Min**	**Median**	**Count**
Primary forest	137	39.16	17.51	207	116	118	5
Secondary forest	47	13.16	1.24	105	27	46	112
Disturbed secondary forest	34	18.08	3.01	74	7	27	36
Early secondary growth	13	4.16	0.41	30	4	12	101
Plantation	9	-	-	-	-	9	1
Riparian forest	11	-	-	-	-	11	1
Pasture with high tree cover	62	49.88	11.76	159	11	44	18
Pasture with low tree cover	9	2.52	0.89	13	5	9	8
Pasture with no tree cover	0	-	-	-	-	0	1
Perennial crop, conventional with multistrata shade	27	11.50	4.35	46	15	24	7
Perennial crop, conventional, with one stratum shade	10	3.63	0.33	18	2	10	121
Annual crop, conventional, with one stratum shade	2	-	-	-	-	2	1
Annual crop, conventional	0	-	-	-	-	0	1

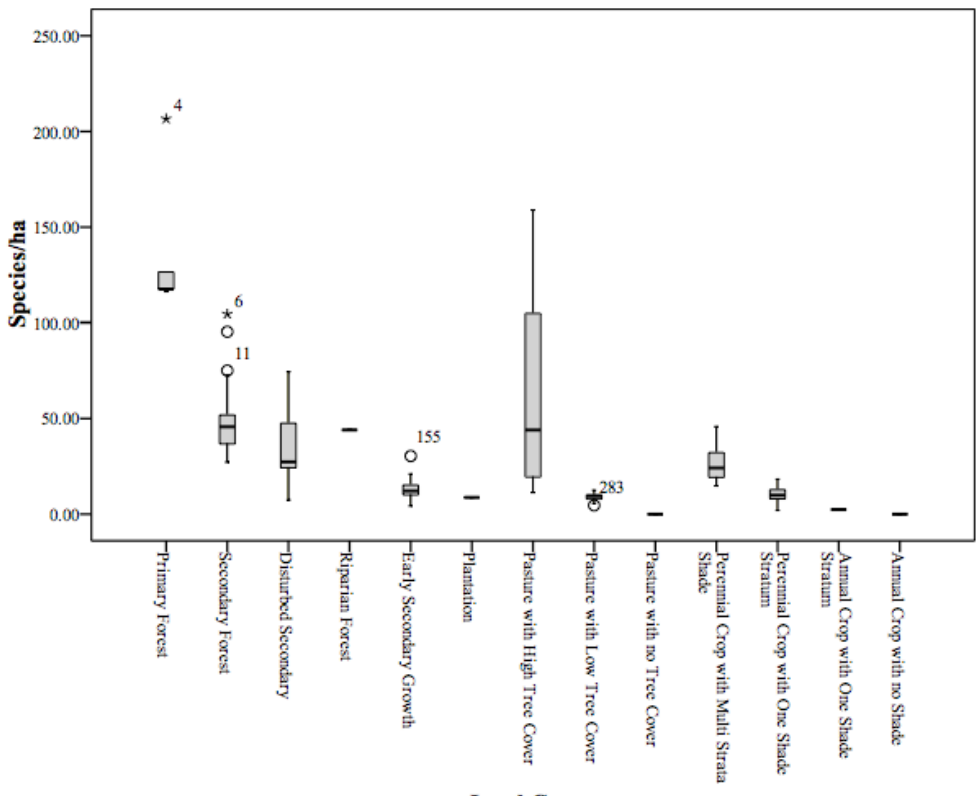


Fig. 3-6: Boxplot of the species per hectare of thirteen land use types calculated for the tropical moist forest area.

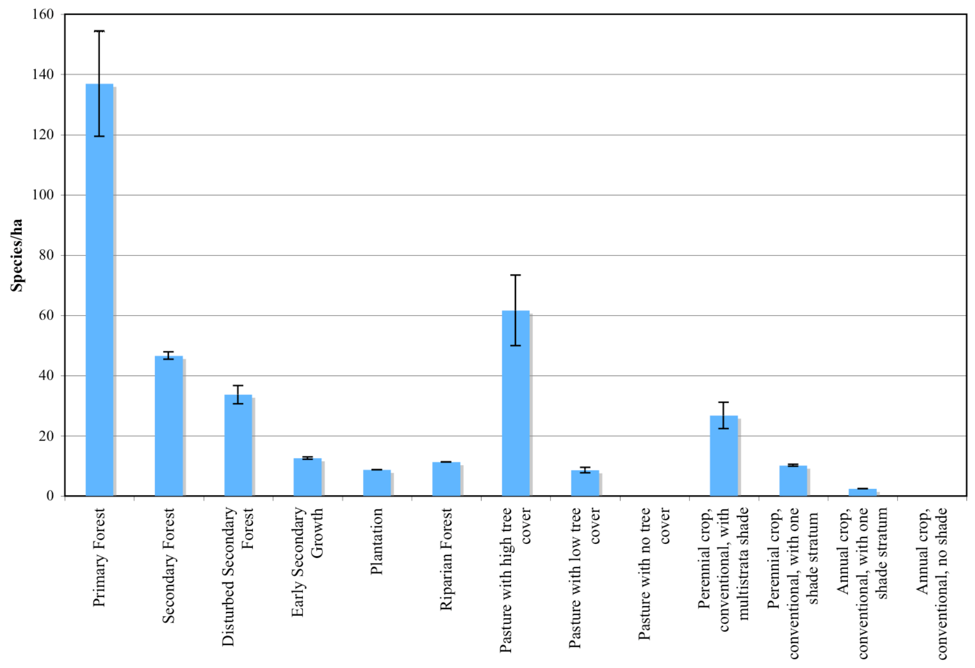


Fig. 3-7: The means of species (d.h.b ≥ 10cm) in one hectare of thirteen different types of land cover in the tropical moist forest area (+/- standard error).

Tab. 3-3: Mean of the standardized species number S for different types of land use concerning the tropical dry forest. The standardized species number S refers to the $A_{standard}$ = 1 ha.

Land use	**Mean**	**St Dev**	**St Error**	**Max**	**Min**	**Median**	**Count**
Primary Forest	44	27.31	2.98	137	13	33	84
Secondary Forest	30	13.10	9.27	39	21	30	2
Disturbed Secondary Forest	12	4.31	1.76	20	8	11	6
Early Secondary Growth	22	5.73	3.52	45	7	19	10
Riparian Forest	18	19.13	13.52	32	5	18	2
Pasture High Tree Cover	16	10.46	2.62	45	4	14	16
Pasture Low Tree Cover	5	7.24	2.41	24	1	2	9
Forest and crop	51	22.36	5.59	125	27	45	16
Perennial, organic with multistrata shade	18	5.13	1.04	25	10	18	17
Perennial, conventional, with multistrata shade	12	4.30	0.82	23	3	11	39
Perennial, organic, shaded	14	3.51	0.85	19	7	15	17
Perennial, conventional, shaded	11	3.40	0.91	16	7	13	14
Perennial conventional, no shade	10	-	-	-	-	10	1

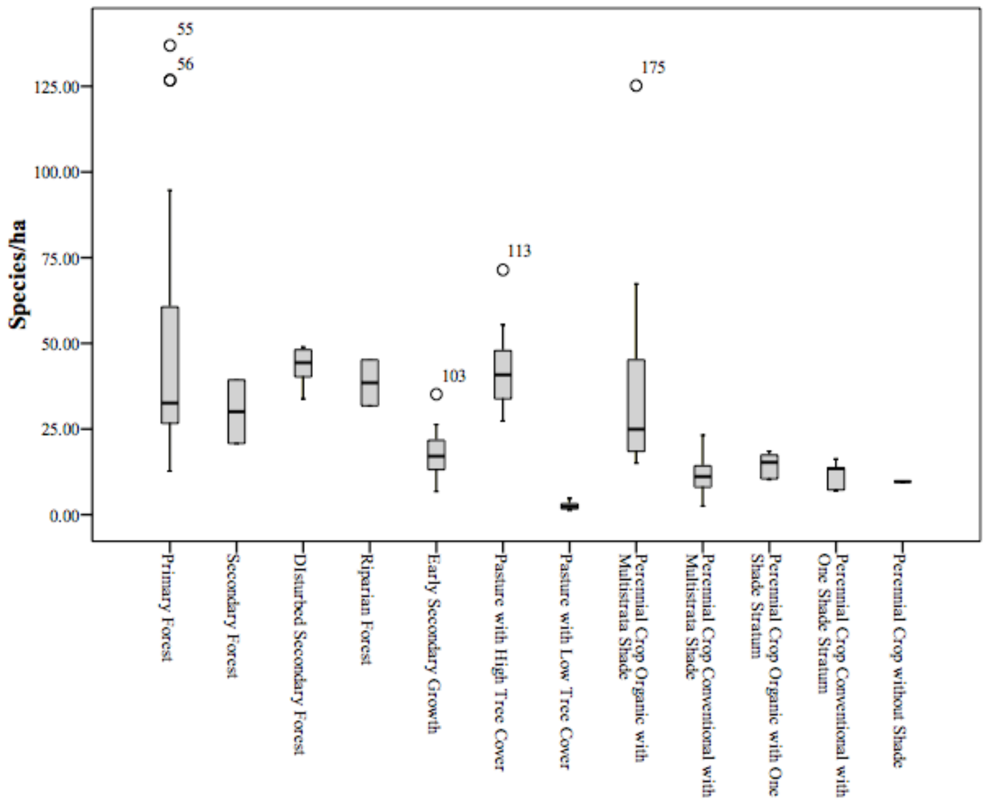


Fig. 3-8: Boxplot of the species per hectare of thirteen land use types calculated for the tropical dry forest area.

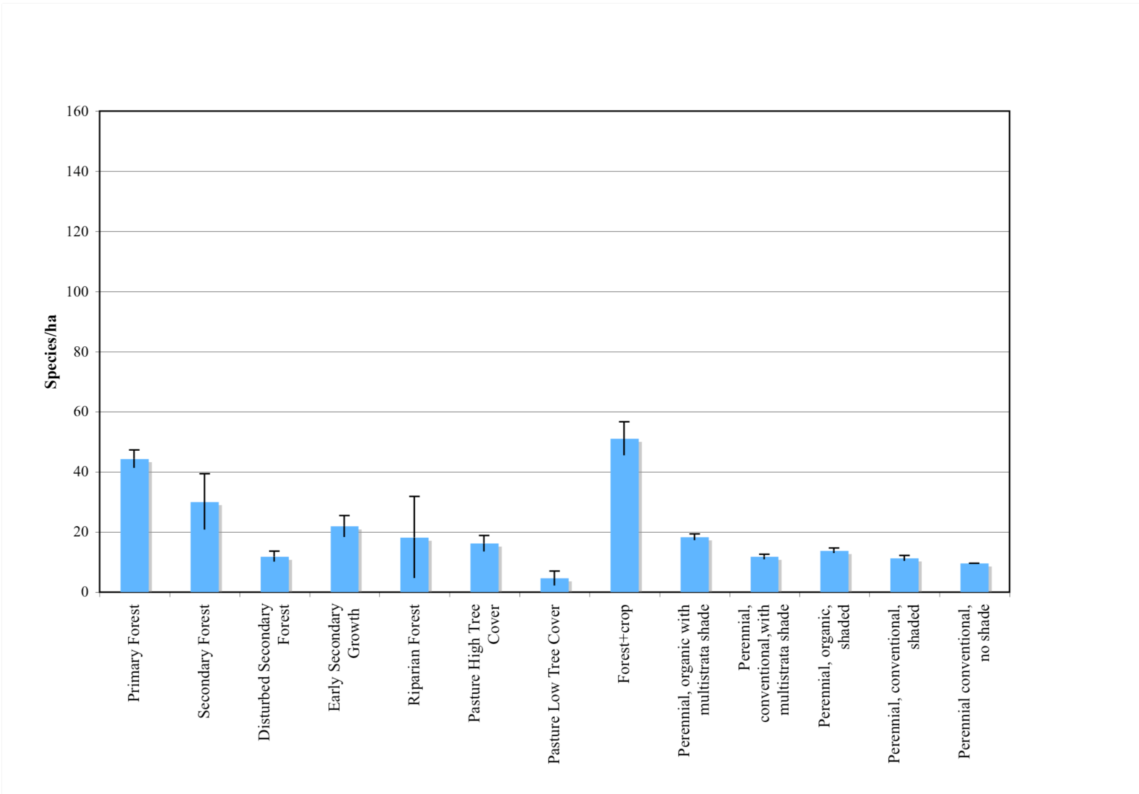


Fig. 3-9: Means of species (d.h.b ≥ 10cm) per hectare of thirteen different types of land cover in the tropical dry forest area (+/- standard error).

3.1.3. Statistical comparison of the meta-analysis results

I ran two tests to compare the results of the three life zones. I started with an ANOVA test in order to assess the similarity of the means between land cover types in the three life zones. The F values of the 10 land cover types analyzed were > 8 and showed a $p < 0.05$, only the results of the land uses disturbed secondary forest (F = 0.999, p = 0.376) and perennial (semi-) crop, conventional with one shade stratum (F = 0.755, p = 0.378) showed a F value that doesn't reject the H_0-hypothesis. The H_0-hypothesis supports the fact that the number of plant species on a land cover type is similar between the life zones evaluated in this work (Complete results' table of the ANOVA test in Appendix 7).

Afterwards I performed a Bonferoni Post Hoc test in order to compare the results of just two life zones at the time, 60% of the comparisons shows a mean difference significant on a 0.05 level (results are showed in the Appendix 7).

3.1.4. Herbaceous plants and vascular plants data

The data concerning the herbaceous and shrub plants or the total number of vascular plants are insufficient to perform a meta-analysis or use different criteria to distinguish the types of plants. However shrub and herbaceous plants are important for the biodiversity conservation and the previous studies on the land use impact on biodiversity investigate the total vascular plant species as an indicator. For these reason I insert the results on herbaceous and shrub plants of four projects carried out on different land use types.

Tab. 3-4: Species number of herbs and woody plants of two landscape in the tropical wet forest of Ecuador. The woody plants represent the vascular plants with d.h.b. ≥ 10 cm. The herb plants represent the vascular plants with d.h.b. <10 cm. Low impact landscape is a region with a low anthropogenic impact. The high impact landscape is a region dominated by agroforestry system, pasture and plantation, with highly fragmented forest (Lozada 2006).

	Low impact lanscape		**High impact landscape**	
	Herbs /0.25 ha	Woody plants /0.25 ha	Herbs /0.25 ha	Woody plants /0.25 ha
Rice	25	-	46	-
Pasture	34	-	48	-
Managed Agroforestry	27	27	18	13
Abandoned Agroforestry	16	58	35	42
Disturbed Secondary Forest	11	57	26	53
Landscape vascular plants (per 7.5 ha):	107	185	233	165

Tab. 3-5: Herbaceous and shrub plants species number relative to three types of pastures in the tropical dry forest life zone of Nicaragua. For each pasture method eight farms are investigated (Ospina 2005).

	Animal Unit/ha	**Nr. Transect of 50m**	**Herbs and shrubs (d.h.b. ≤ 8cm)**
High Impact	1.2-1.7	110	112
Low Impact Pasture	0.7-0.9	120	147
Low Impact Pasture	0.5-0.8	140	153

Tab. 3-6: Species number of herbs and shrubs (d.h.b. ≥ 2.5 cm and ≤ 9.9 cm) in a tropical moist forest region in Costa Rica (Brown Salazar 2000).

	Herbs and shrubs (d.h.b. ≥ 2.5 cm and ≤ 9.9 cm)			
	0.5 hectare	**1 hectare**	**1.5 hectare**	**2 hectare**
Secondary forest disturbed	40	62	75	82
Secondary forest undisturbed	37	55	64	70

Tab. 3-7: Vascular plant species in perennial crop (D. marginata) plantations in the tropical moist forest in Costa Rica (Villalobos 2007).

	0.025 (ha)	**0.05 (ha)**	**0.075 (ha)**	**0.1 (ha)**	**0.125 (ha)**	**0.15 (ha)**	**0.175 (ha)**	**0.2 (ha)**	**0.225 (ha)**
Between two crop field	10	15	20	23	27	29	30	32	34
Drainage	14	22	28	32	38	40	42	45	47
Perennial crop field	14	23	31	34	40	44	48	50	52

3.2. *Survey*

3.2.1. Course of the survey

The survey's questionnaire was sent on the 14. December 2007 in English and Spanish. 170 experts have been asked to compile the survey in a first place. The experts were divided according to their countries and main topics of research in order to have almost equal representatives for every region of Latin America and for each type of research area.

The initial planned deadline was scheduled for the 15th January 2008. On the 14th of January a recall was sent and the deadline was postponed on the 25th January 2008 giving more time for filling in the questionnaire. Postponing the deadline was necessary because the Christmas vacations were situated right before the first deadline. On the 15th of January I sent the survey to 13 new experts. The deadline established for this second set of survey was the 15th of February 2008. The names of the 13 new experts were suggested by some of the experts included on the initial experts' list.

The final total amount of experts who received the survey is 183. From these 183 experts 20 filled in the questionnaire, other 13 answered that the survey topic didn't match their research area and in some cases they suggested the name of colleagues more qualified for the purpose of the survey.

Ta.b 3-8: Number of experts who answered to the inquiry and number of questionnaire filled out respect to the total number of experts asked.

Reaction of the experts	Number	Percent
Nr. of questionnaires filled before the 14th Jan 2008	5	3%
Total nr. of filled questionnaires	20	11%
Nr. of experts that answered that the survey doesn't match their research area	13	7%
Total nr. of experts	183	100%

According to the Holdridge's life zones indicated by the experts, the survey's results can be divided in six groups, as shown in the Tab. 3-9. The biodiversity evaluations concern six of the Holdridge's life zones: tropical wet forest, tropical moist forest, tropical dry forest, subtropical wet forest, subtropical moist forest and subtropical dry forest, although not all life zones are equally represented. Some of the experts indicated that their answers are valid for more than one life zone. Tab. 3-9 indicates the countries where the experts who filled in the questionnaire carry out their research work. The complete list with the experts' name and institution is shown in Appendix 4.

Tab. 3-9: Holdridge's life zones and countries taken as a reference for the filling in of the questionnaires.

Holdridge's life zones	Number of evaluations	Region (nr. of evaluations)
Tropical Dry Forest	5	Brazil (2)

Holdridge's life zones	Number of evaluations	Region (nr. of evaluations)
Tropical Moist Forest	4	Costa Rica (2) Honduras (1) Central America (1) Columbia (1)
Tropical Wet Forest	6	Costa Rica (2) Brazil (1) Central America (1) Costa Rica (4)
Subtropical Dry Forest	1	Bolivia (1)
Subtropical Moist Forest	3	Bolivia (1) Brazil (2)
Subtropical Wet Forest	2	Bolivia (1) Costa Rica (1)

3.2.2. Biodiversity evaluations for tropical life zones

The experts could insert an evaluation for the land cover types on which they work or about which they felt more comfortable to do an evaluation. Therefore, not all the land cover types have the same number of experts' evaluations.

In the Tab. 3-10, 3-11 and 3-12 are showed the results of the analysis of the experts' evaluation. The mean for every land cover, is represented in a scale 0 to 10, where 10 corresponds to the land cover with the higher vascular plants level and 0 indicates the land cover with the smallest diversity. Standard deviation, standard error and the number of evaluation are also indicated. Fig. 3-10, 3-11 and 3-12 show the graphic results of the evaluation. I reported the complete data just relative to the Holdridge's life zone, tropical dry forest, tropical moist forest and tropical wet forest because are the regions with the major number of experts' evaluations.

Tab. 3-10: Data of the questionnaires concerning the tropical dry forest (the data are represented on a scale 0 to 10, with 10 corresponding with the land cover with the highest biodiversity level).

Level 1	Level 2	Mean	St. Dev.	St. Error	Count
Forest	Primary forest, undisturbed	9.25	1.5	0.75	4
	Mature forest	8.8	1.3	0.58	5
	Secondary forest	6.6	1.34	0.6	5
	Disturbed secondary forest	5.6	0.89	0.4	5
	Early secondary growth	3.25	1.71	0.85	4
	Plantation	2.4	1.67	0.75	5
Wetland	Tree cover, regularly flooded, fresh water	7.5	3	1.5	4
	Tree cover, regularly flooded, saline water	4	2.65	1.53	3
	Regularly flooded shrub/herbaceous cover	5.75	1.5	0.75	4
Shrublands	Shrub cover, closed-open, no tree cover	4.67	2.52	1.45	3
	Shrub cover, closed-open, tree cover	6.67	1.15	0.67	3

Level 1	Level 2	Mean	St. Dev.	St. Error	Count
	Sparse shrub/herbaceous cover	7.67	0.58	0.33	3
Grassland	Unused without tree cover	4.75	2.06	1.03	4
	Unused with natural tree/shrub cover	6.75	2.2	1.11	4
Pasture	High tree cover, low impact use	5	0.82	0.41	4
	High tree cover, intensive use	2	0.82	0.41	4
	Low tree cover, low impact use	4.5	1	0.5	4
	Low tree cover, intensive use	1.75	0.5	0.25	4
	No tree cover, low impact use	3.5	1.29	0.65	4
	No tree cover, intensive use	1.23	0.5	0.25	4
	Degraded pasture	2	1.41	0.71	4
Agriculture	Perennial or semi-perennial, organic, multi strata tree cover	3.67	1.15	0.67	3
	Perennial or semi-perennial, conventional, multi strata tree cover	3.33	1.15	0.88	3
	Perennial or semi-perennial, organic, with one stratum tree cover	2	1.53	0.58	3
	Perennial or semi-perennial culture, conventional, with one stratum tree cover	2	1	0.58	3
	Annual, organic, multi strata tree cover	3.33	1	0.88	3
	Annual, conventional, multi strata tree cover	3.33	1.53	0.88	3
	Annual, organic with one stratum tree cover	2	1.53	0.58	3
	Annual, conventional with one stratum tree cover	2	1	0.58	3
	Perennial or semi-perennial, organic	3.33	1.53	0.88	3
	Perennial or semi-perennial, conventional	1.67	0.58	0.33	3
	Annual, organic	1	0	0	3
	Annual, conventional	1	0	0	3
	Annual, flooded	1	0	0	3
Artificial	Paved road	0.5	0.58	0.29	4
	Unpaved road	1	0.82	0.41	4
	Rail	2	2.16	1.08	4
Urban	Urban, high density	0.5	0.58	0.29	4
	Urban, medium density	1	0	0	4
	Urban, low density	1.5	0.58	0.2	4
	Urban green areas	2.67	0.58	0.33	3
Industrial	Industrial, high density	0.5	0.58	0.29	4
	Industrial, medium density	0.75	0.5	0.25	4
	Industrial, low density	1.25	0.5	0.25	4
	Waste dump	1.33	0.58	0.33	3
	Extraction site	2	2.16	0	4

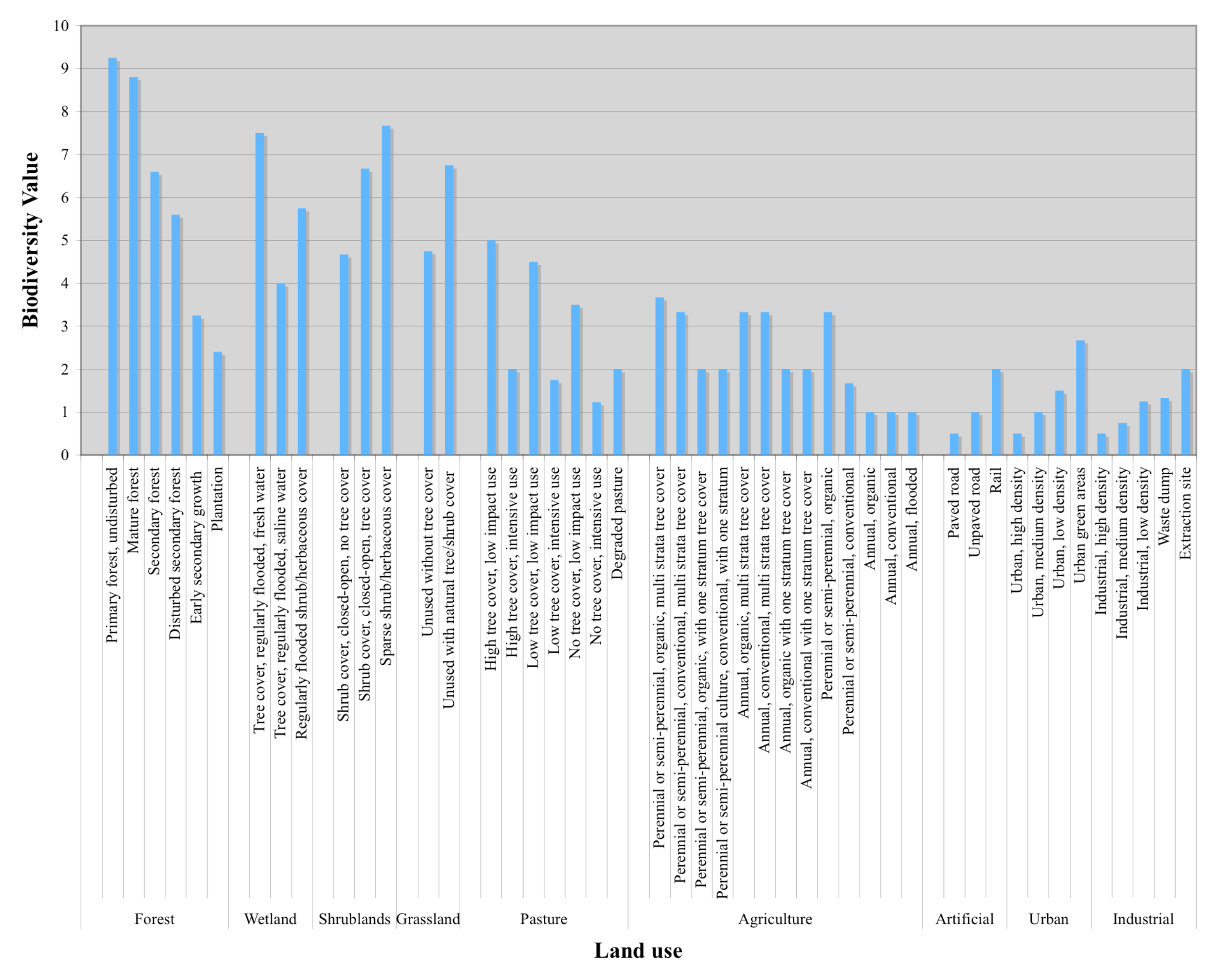


Fig. 3-10: Means of the experts' evaluation for the tropical dry forest.

Tab. 3-11: Data of the questionnaires concerning the tropical moist forest (the data are represented on a scale 0 to 10, with 10 corresponding with the land cover with the highest biodiversity level).

Level 1	Level 2	Mean	St. Dev.	St. Error	Count
Forest	Primary forest, undisturbed	9.75	0.5	0.25	4
	Mature forest	9.67	0.58	0.33	3
	Secondary forest	6.33	1.25	0.88	3
	Disturbed secondary forest	6	1.41	1	2
	Early secondary growth	4	1	0.58	3
	Plantation	4	3.46	2	3
Wetland	Tree cover, regularly flooded, fresh water	8	0	0	1
	Tree cover, regularly flooded, saline water	6	0	0	1
	Regularly flooded shrub/herbaceous cover	9	0	0	1
Shrublands	Shrub cover, closed-open, no tree cover	5.5	0.71	0.5	2
	Shrub cover, closed-open, tree cover	7.5	0.71	0.5	2
	Sparse shrub/herbaceous cover	5.5	3.54	2.5	2
Grassland	Unused without tree cover	6	2.83	2	2
	Unused with natural tree/shrub cover	4	1.41	1	2
Pasture	High tree cover, low impact use	5	0	0	2
	High tree cover, intensive use	4.5	2.12	1.5	2
	Low tree cover, low impact use	4	0	0	2
	Low tree cover, intensive use	2	0	0	2
	No tree cover, low impact use	3	0	0	2
	No tree cover, intensive use	1	0	0	2
	Degraded pasture	1.5	2.12	1.5	2
Agriculture	Perennial or semi-perennial, organic, multi strata tree cover	5.5	2.12	1.5	2
	Perennial or semi-perennial, conventional, multi strata tree cover	5.5	2.12	1.5	2
	Perennial or semi-perennial, organic, with one stratum tree cover	4.5	2.12	1.5	2
	Perennial or semi-perennial culture, conventional, with one stratum tree cover	4	2.83	2	2
	Annual, organic, multi strata tree cover	4.5	2.12	1.5	2
	Annual, conventional, multi strata tree cover	4	2.83	2	2
	Annual, organic with one stratum tree cover	2.5	1.41	1	2
	Annual, conventional with one stratum tree cover	2.5	2.12	1.5	2
	Perennial or semi-perennial, organic	3	1.41	1	2
	Perennial or semi-perennial, conventional	2.5	0.71	0.5	2
	Annual, organic	2	0	0	2
	Annual, conventional	1.5	0.71	0.5	2
	Annual, flooded	1.5	0.71	0.5	2
Artificial	Paved road	0	0	0	2

Level 1	Level 2	Mean	St. Dev.	St. Error	Count
	Unpaved road	0.5	0.71	0.5	2
	Rail	1	1.41	1	2
Urban	Urban, high density	1.5	1.41	1	2
	Urban, medium density	3	1.41	1	2
	Urban, low density	4	1.41	1	2
	Urban green areas	4.5	0.711	0.5	2
Industrial	Industrial, high density	0.5	0.71	0.5	2
	Industrial, medium density	1.5	0.71	0.5	2
	Industrial, low density	2.5	0.71	0.5	2
	Waste dump	0	0	0	2
	Extraction site	0.5	0.71	0.5	2

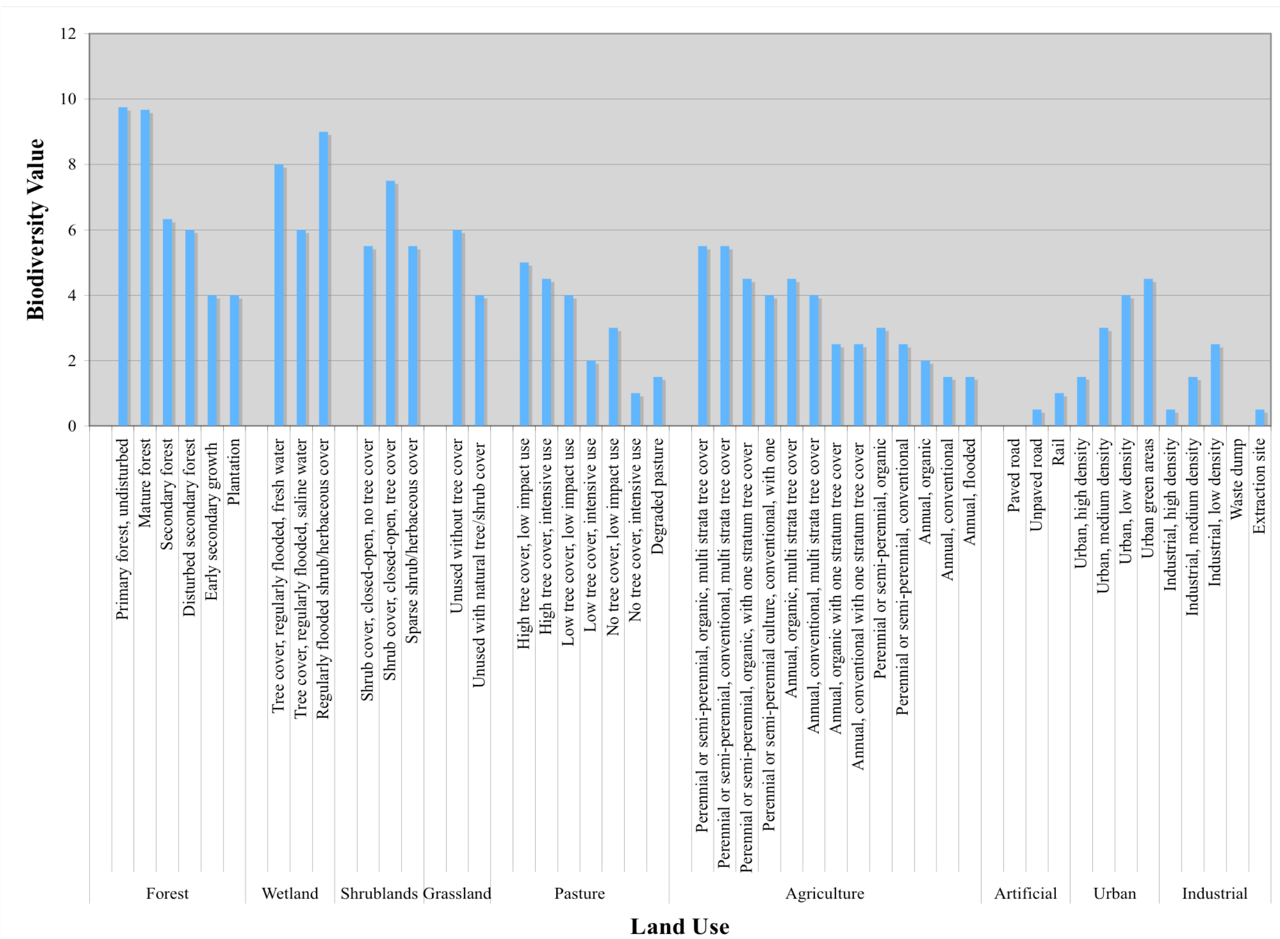


Fig. 3-11: Means of the experts' evaluation for the tropical moist forest.

Tab. 3-12: Data from the questionnaires concerning the tropical wet forest.

Level 1	Level 2	Mean	St. Dev.	St. Error	Count
Forest	Primary forest, undisturbed	10	0	0	6
	Mature forest	9	0.82	0.31	7
	Secondary forest	6.4	0.55	0.24	5
	Disturbed secondary forest	5	0.71	0.32	5
	Early secondary growth	4.14	1.21	0.46	7
	Plantation	4.29	3.04	1.15	7
Wetland	Tree cover, regularly flooded, fresh water	5.75	2.06	1.03	4
	Tree cover, regularly flooded, saline water	3.75	1.5	0.75	4
	Regularly flooded shrub/herbaceous cover	4.74	3.1	1.55	4
Shrublands	Shrub cover, closed-open, no tree cover	4.83	0.98	0.4	6
	Shrub cover, closed-open, tree cover	6.67	1.37	0.56	6
	Sparse shrub/herbaceous cover	3.67	2.16	0.88	6
Grassland	Unused without tree cover	5	2.37	0.97	6
	Unused with natural tree/shrub cover	3.29	1.5	0.57	7
Pasture	High tree cover, low impact use	3.25	1.71	0.85	4
	High tree cover, intensive use	3	2.16	1.08	4
	Low tree cover, low impact use	3.6	1.52	0.68	5
	Low tree cover, intensive use	2.8	1.3	0.58	5
	No tree cover, low impact use	2.75	0.96	0.48	4
	No tree cover, intensive use	1.75	0.96	0.48	4
	Degraded pasture	1	0.71	0.32	5
Agriculture	Perennial or semi-perennial, organic, multi strata tree cover	6.25	1.71	0.85	4
	Perennial or semi-perennial, conventional, multi strata tree cover	5.25	1.5	0.75	4
	Perennial or semi-perennial, organic, with one stratum tree cover	5.75	2.06	1.03	4
	Perennial or semi-perennial culture, conventional, with one stratum tree cover	5.5	1.29	0.65	4
	Annual, organic, multi strata tree cover	5.25	3.4	1.7	4
	Annual, conventional, multi strata tree cover	4.25	2.63	1.31	4
	Annual, organic with one stratum tree cover	4.67	2.31	1.33	
	Annual, conventional with one stratum tree cover	5	2.58	1.29	4
	Perennial or semi-perennial, organic	2.33	0.58	0.33	4
	Perennial or semi-perennial, conventional	2	0	0	4
	Annual, organic	2	1	0.58	4
	Annual, conventional	1.67	0.58	0.33	4
	Annual, flooded	1.67	0.58	0.33	4
Artificial	Paved road	0	0	0	3
	Unpaved road	1.33	1.53	0.88	3
	Rail	1.67	1.53	0.88	3

Level 1	Level 2	Mean	St. Dev.	St. Error	Count
Urban	Urban, high density	1.33	1.33	0.88	3
	Urban, medium density	2	2	1.15	3
	Urban, low density	2.67	2.67	1.45	3
	Urban green areas	3	3	1.15	3
Industrial	Industrial, high density	0.33	0.33	0.33	3
	Industrial, medium density	1.33	1.33	0.67	3
	Industrial, low density	2	1.73	1	3
	Waste dump	0.33	0.58	0.33	3
	Extraction site	0.67	1.15	0.67	3

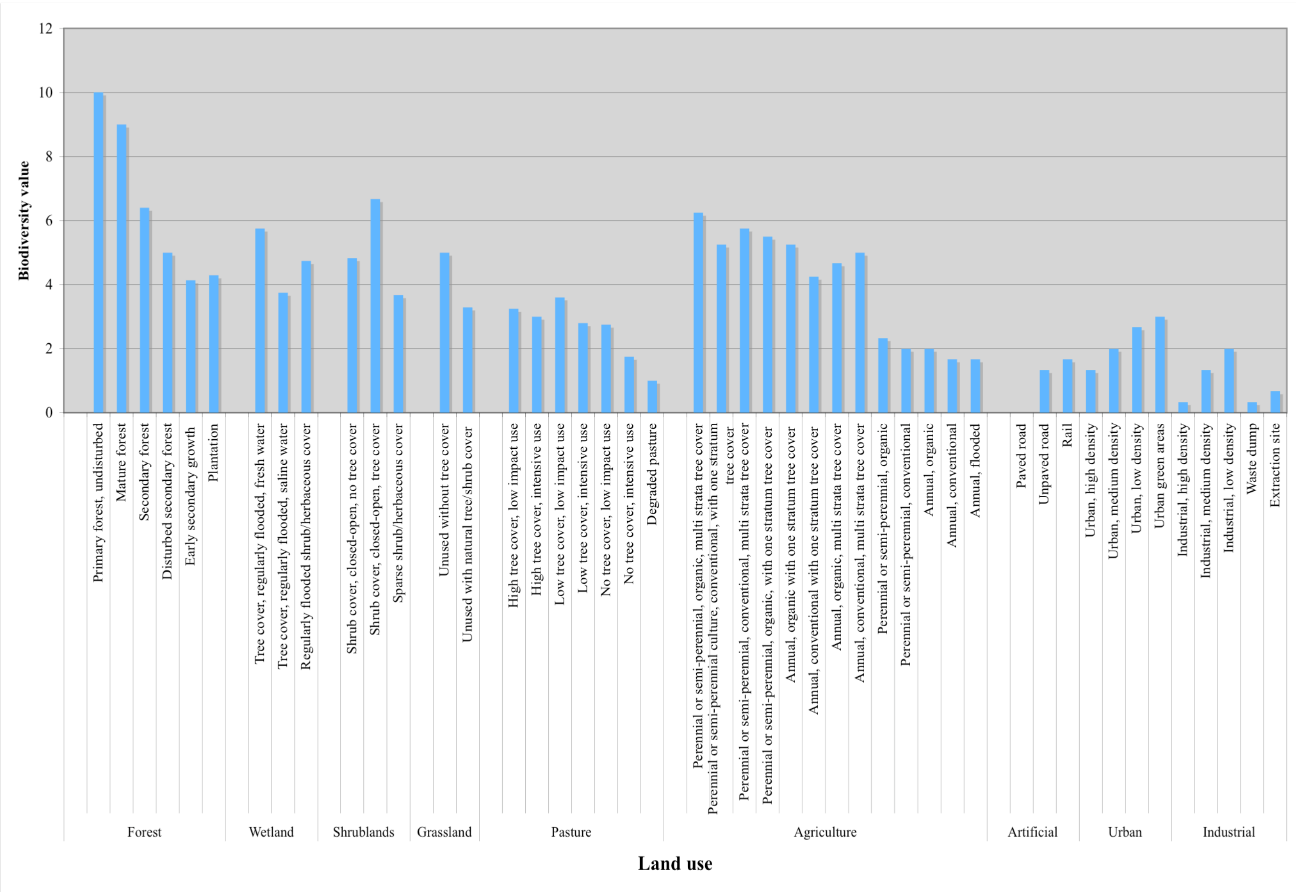


Fig. 3-12: Evaluations' means for the tropical wet forest.

3.2.3. Biodiversity evaluation for the subtropical life zones

As mentioned before, the majority of the experts gave an evaluation for the three tropical life zones, however some experts also evaluated the three subtropical regions of Latin America. The quantity of questionnaires filled in for these regions is too small so I performed only a partial analysis of the data. The results are shown in the Tab 3-13 and in Fig. 3-13.

Tab. 3-13: Mean of the experts' biodiversity evaluations on a scale from 0 to 10, with 10 corresponding to the land use with the higher vascular plant biodiversity. The data concern the Holdridge's life zones subtropical dry, moist and wet forest.

		Dry	**Moist**				**Wet**	
Level 1	**Level 2**	**Mean**	**Mean**	**St. Dev.**	**St. Error**	**Count**	**Mean**	**Count**
Forest	Primary forest, undisturbed	10	9.67	0.58	0.33	3	10	2
	Mature forest	10	9	1	0.58	3	10	2
	Secondary forest	10	8.33	2.08	1.2	3	7.5	2
	Disturbed secondary forest	6	6.33	1.53	0.88	3	5	2
	Early secondary growth	5	6	2.65	1.53	3	4	2
	Plantation	3	3.67	2.08	1.2	3	2	2
Wetland	Tree cover, regularly flooded, fresh water	8	6.67	1.15	0.67	3	7	2
	Tree cover, regularly flooded, saline water					0	4	1
	Regularly flooded shrub/herbaceous cover	7	4.67	2.52	1.45	3	4	2
Shrublands	Shrub cover, closed-open, no tree cover	7	5	0	0	2	4	2
	Shrub cover, closed-open, tree cover	3	6.5	0.71	0.5	2	5	2
	Sparse shrub/herbaceous cover	3	3	0	0	2	2	2
Grassland	Unused without tree cover	3	5	2.83	2	2	2.5	2
	Unused with natural tree/shrub cover	2	3.5	2.12	1.5	2	3	
Pasture	High tree cover, low impact use	2	4	2.83	2	2	2.5	2
	High tree cover, intensive use	1	3	2.83	2	2	1	2
	Low tree cover, low impact use	3	4	1.41	1	2	2.5	2
	Low tree cover, intensive use	2	3	1	0.58	3	2	2
	No tree cover, low impact use	2	2.5	0.71	0.5	2	1.5	2
	No tree cover, intensive use	1	1.67	0.58	0.33	3	0.5	2
	Degraded pasture	1	1.5	0.71	0.5	2	0.5	2
Agriculture	Perennial or semi-perennial, organic, multi strata tree cover	2	5	4.24	3	2	3	2
	Perennial or semi-perennial, conventional, multi strata tree cover	1	4	4.24	3	2	2	2
	Perennial or semi-perennial, organic, with one stratum tree cover	1	4	4.24	3	2	2	2
	Perennial or semi-perennial culture, conventional, with one stratum tree cover	0	3	4.24	3	2	1	2
	Annual, organic, multi strata tree cover	2	4	2.83	2	2	3.5	2

		Dry	Moist				Wet	
Level 1	**Level 2**	**Mean**	**Mean**	**St. Dev.**	**St. Error**	**Count**	**Mean**	**Count**
	Annual, conventional, multi strata tree cover	1	3	2.83	2	2	1.5	2
	Annual, conventional with one stratum tree cover	0	2	2.83	2	2	0.5	2
	Annual, organic with one stratum tree cover	1	3	2.83	2	2	1.5	2
	Perennial or semi-perennial, organic	4	4.5	0.71	0.5	2	3.5	2
	Perennial or semi-perennial, conventional	2	3	1.41	1	2	2	2
	Annual, organic	1	2	1.41	1	2	1.5	2
	Annual, conventional	0	1	1.41	1	2	0.5	2
	Annual, flooded	0	0.5	0.71	0.5	2	0	2
Artificial	Paved road	0	0.33	0.58	0.33	3	0	2
	Unpaved road	0	0.33	0.58	0.33	3	0.5	2
	Rail	0	0.5	0.71	0.5	3	0	2
Urban	Urban, high density	0	1	1	0.58	3	0	2
	Urban, medium density	0	1	1	0.33	3	0.5	2
	Urban, low density	0	0.33	0.58	0.88	3	1	2
	Urban green areas	4	2.67	1.53	0.33	3	3	2
Industrial	Industrial, high density	0	0.33	0.58	0.33	3	0	2
	Industrial, medium density	0	0.33	0.58	0.33	3	0	2
	Industrial, low density	0	0.33	0.58	0.33	3	0	2
	Waste dump	0	0.33	0.58	0.33	3	0	2
	Extraction site	0	0.5	0.71	0.5	2	0	1

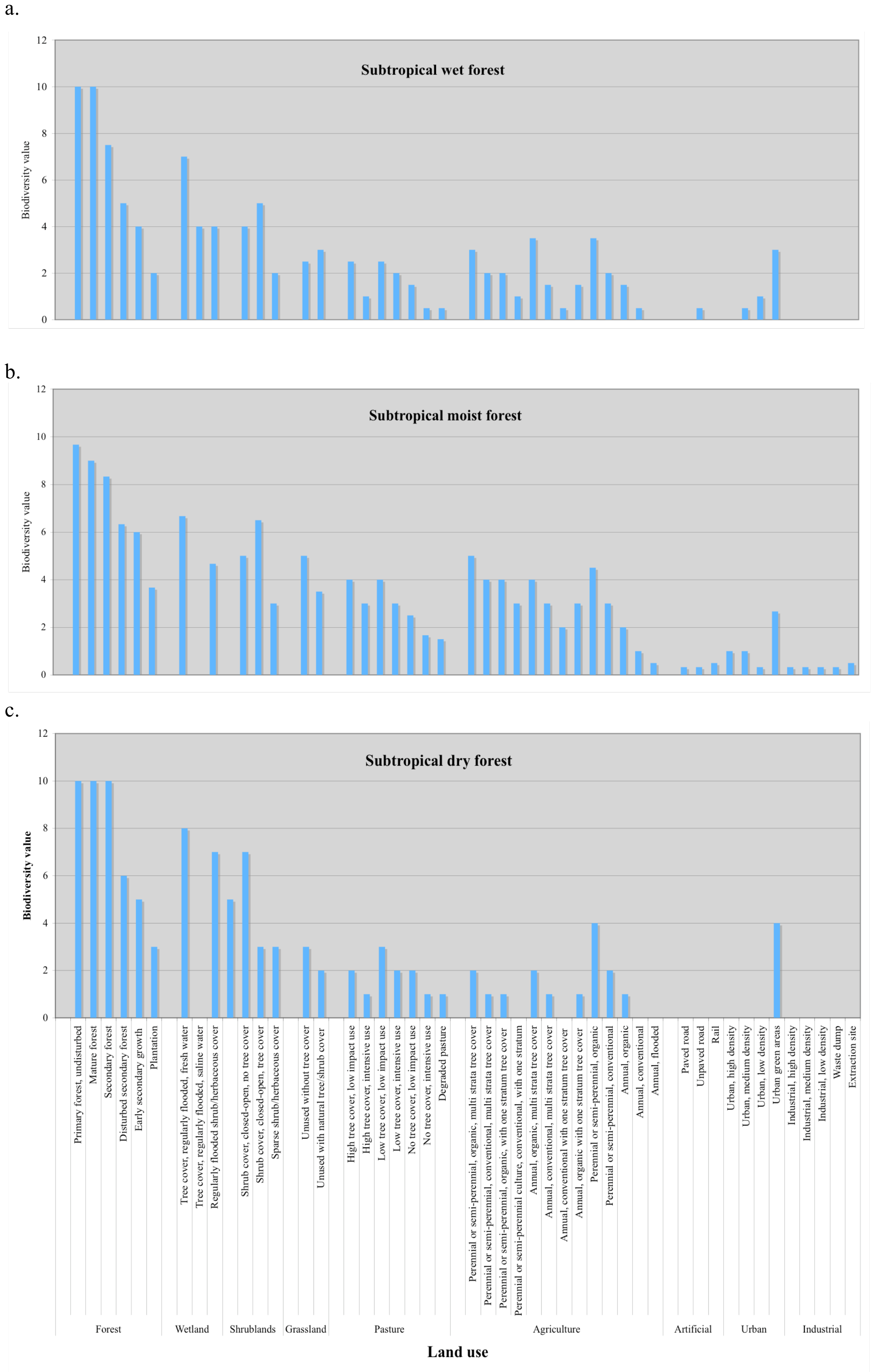


Fig. 3-13: Experts' biodiversity evaluations for the subtropical wet(a), moist(b) and dry(c) forests.

3.2.4. Implementation of biodiversity and production

The second question aims to gather experts' opinion on the best land use combination in order to improve, at the same time, biodiversity conservation and productivity of a determinate area. The experts had to choose three land uses of the third level of GLC2000+, whose combination would improve the two factors mentioned above. Table 3-14 shows the combinations chosen by the experts and their frequency. The combinations' choice wasn't homogeneous, only the combination between undisturbed primary forest, grassland with high tree cover and low impact use and the perennial crop, organic with multistrata shade was chosen 4 times. In order to have a better overview of the results the land use types are grouped according to the second level of the GLC2000 + classification even if the experts chose between the land use types on the third level. Tab. 3-14 shows the opinions of 17 out of 20 experts who answered to the survey. The rest of the experts either didn't give an opinion on this topic or didn't complete the questionnaire in the proper manner.

Tab. 3-14: The combinations of three land use types that according to the experts' opinions cause the maximal implementation of biodiversity conservation and of the productivity of a territory. The experts' choice is depicted here on the second level of the GLC2000+ land cover classification

	Combination of three land uses	**Nr. of experts who chose this combination**
1.	Forest Grassland (pasture) Mosaic: agriculture land, tree cover	9
2.	Forest Forest Forest	2
3.	Forest Grassland (pasture) Agriculture	2
5.	Forest Agriculture Mosaic: agriculture land, tree cover	1
9.	Forest Agriculture Agriculture	1
12.	Grassland Grassland Mosaic: agriculture land, tree cover	1
13.	Mosaic: agriculture land, tree cover Mosaic: agriculture land, tree cover Mosaic: agriculture land, tree cover	1

3.2.5. Opinion about the methodology applied in this survey

In this survey the number of vascular plant species is taken as a proxy for the whole biodiversity that characterizes a land cover. In the second part of the survey the experts had to give their opinion in regard to this choice.

The majority of the experts (60%) think that the use of vascular plants as a representative of biodiversity is a good choice. An other 15% of the experts think that this choice is justified until a certain extent and 15 % don't agree because the importance of the inter species diversity and the difficulty of evaluating the effect of exotic and invasive species are left out. 10 % of the experts didn't express themselves on this matter.

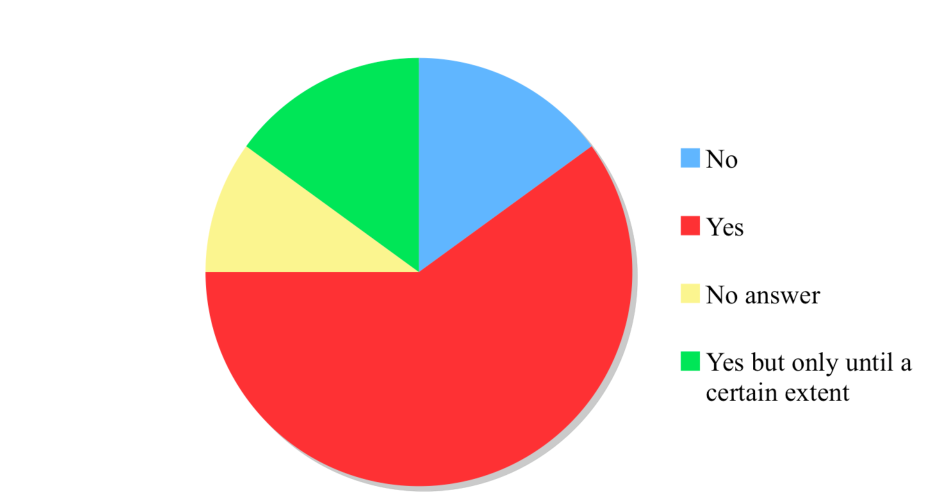


Fig. 3-14: Distribution of the experts' opinion pertaining to the choice of using the vascular plant species as a proxy for the whole biodiversity of a land cover.

3.2.6. Statistical comparison between life zones

I ran an ANOVA test in order to analyze the similarity of the experts' responses for each type of land use of the three Holdridge's life zones tropical wet, moist and dry forest. The results of the tests indicate that 22 of the 46 land cover types have a F-ratio greater than 1. This means that for these cases the hypothesis of similarity between the groups couldn't be rejected. However the majority of the tests showed a $p > 0.05$ (complete table in Appendix 5) and indicates a non-significant statistical result.

A Post Hoc test for the comparison between two life zones was also performed. The complete results of the Post Hoc test are shown in Appendix 5.

3.2.7. Evaluation of the absolute number of vascular plant species

As optional question the experts had the possibility to insert an estimation of the absolute number of vascular plant species that could be found in one hectare of the different land cover types. Four of the experts expressed their opinion on the tropical wet, moist and dry forests. The evaluations are shown in the Tab 3-15.

Tab. 3-15: Experts' evaluation concerning the absolute number of vascular plant species that can be found in one hectare of different land use types (TWF = tropical wet forest; TMD = tropical moist forest; TDF = tropical dry forest). Only the data concerning expert 4 are expressed in term of plant species with d.h.b. ≥ 10 cm (the result concerns the tropical wet forest). Parenthetical are shown the minimum and maximum species per hectare.*

		Vascular plants			Plants with d.h.b. ≥ 10 cm
		Expert 1	**Expert 2**	**Expert 3**	**Expert 4**
Land use type	Life zones:	TWF	TWF/TMF	TDF	TDF/TWF*
Forest	Primary forest, undisturbed	-	-	120 (50-150)	-
	Mature forest	80 (-)	450 (150-450)	80 (20-100)	97* (-)
	Secondary forest	40 (-)	-	45 (10-60)	41 (37-41)
	Disturbed secondary forest	20 (-)	-	30 (10-45)	34 (34-37)
	Early secondary growth	20 (-)	-	15 (5-20)	-
	Plantation	10 (-)	60 (20-100)	5 (1-10)	-
Wetland	Tree cover, regularly flooded, fresh water	-	-	50 (10-60)	-
	Tree cover, regularly flooded, saline water	-	-	5 (1-10)	-
	Regularly flooded shrub/herbaceous cover	-	-	20 (5-30)	-
Shrublands	Shrub cover, closed-open, no tree cover	-	15-30 (5-30)	-	-
	Shrub cover, closed-open, tree cover	-	20-50 (5-30)	-	-
	Sparse shrub/herbaceous cover	-	10-30 (5-30)	-	-
Grassland	Unused without tree cover	10 (-)	-	30 (20-45)	-
	Unused with natural tree/shrub cover	-	-	15 (10-25)	-
Pasture	No tree cover, low impact use	-	-	10 (5-15)	-
	No tree cover, intensive use	-	-	5 (2-10)	-
	Low tree cover, low impact use	10 (-)	-	7 (5-12)	-
	Low tree cover, intensive use	5 (-)	-	8 (3-10)	-
	High tree cover, low impact use	-	-	10 (5-20)	-
	High tree cover, intensive use	-	-	8	-

		Vascular plants			Plants with d.h.b. ≥ 10 cm
		Expert 1	**Expert 2**	**Expert 3**	**Expert 4**
Land use type	Life zones:	TWF	TWF/TMF	TDF	TDF/TWF*
				(5-16)	
	Degraded pasture	5 (-)	-	10 (3-15)	-
Agriculture	Perennial or semi-perennial, conventional	-	-	-	-
	Perennial or semi-perennial, organic	-	-	-	-
	Annual, conventional	-	-	-	-
	Annual, organic	-	-	-	-
	Annual, flooded	-	-	-	-
	Annual, conventional with one stratum tree cover	5 (-)	-	-	-
	Annual, organic with one stratum tree cover	8 (-)	-	-	-
	Annual, conventional, multi strata tree cover	10 (-)	-	-	-
	Annual, organic, multi strata tree cover	-	-	-	-
	Perennial or semi-perennial culture, conventional, with one stratum tree cover	10 (-)	-	-	-
	Perennial or semi-perennial, organic, with one stratum tree cover	10 (-)	-	-	-
	Perennial or semi-perennial, conventional, multi strata tree cover	15 (-)	-	-	-
	Perennial or semi-perennial, organic, multi strata tree cover	15 (-)	-	-	-

3.3. Comparison between database and survey results

Since I have performed two kinds of experiments that aim to measure the level of biodiversity on different land use types, it is interesting to see wetter the trend resulting from the first analysis matches the trend resulting from the second analysis.

3.3.1. Graphic comparison of mean and median

I graphically represent the results of the two experiments for a visual comparison. The first experiment is the meta-analysis of published data regarding the species number of vascular plants with d.h.b. ≥ 10 cm, the second experiment is the experts' survey based on evaluations (scale 0 to 10) about the amount of vascular plant biodiversity on diverse land cover types.

The results of the two analysis show different measures; the first analysis presents the data as absolute number of species, while the measure of the first analysis is a scale from 0 to 10. For this reason I decided to transform the first set of data also to a scale from 0 to 10 in order to perform the comparison (10 corresponds to the higher number of species per hectare that I found in the meta-analysis considering each land use types).

Since the amount of land cover types analyzed in the two experiments is different and does not matches in every case, I compared only the land cover types for which I had values in both experiments.

Tab. 3-16: Survey and database means for the tropical dry forest on a scale from 0 to 10 (In this case the maximal biodiversity value for the database results corresponds to the mix between forest and crop, denominated "forest + crop" in the publications consulted. This land use is not represented in the table because there are not correspondent in the survey data).

	Mean Survey	**Mean Database**
Primary forest	9.25	8.69
Secondary forest	6.75	5.89
Disturbed secondary forest	5.75	2.33
Early secondary growth	3.25	4.30
Pasture with high tree cover	5	3.18
Pasture low tree cover	4.5	0.91
Perennial crop, organic mutistrata shaded	3.67	3.60
Perennial crop, conventional multistrata shaded	3.33	2.31
Perennial crop, organic, shaded	2	2.70
Perennial crop, conventional, shaded	2	2.21
Perennial crop, conventional, no shade	2	1.89

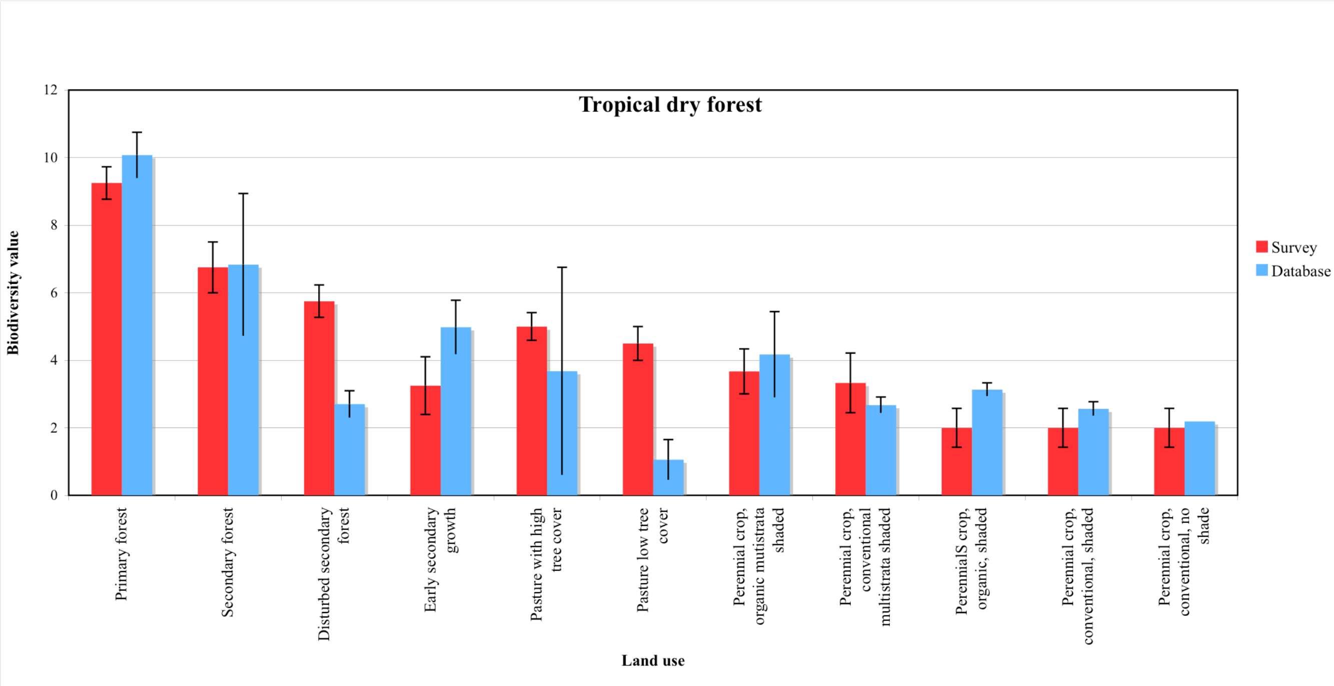


Fig. 3-15: Survey and database results for the tropical dry forest on a 0 to 10 scale.

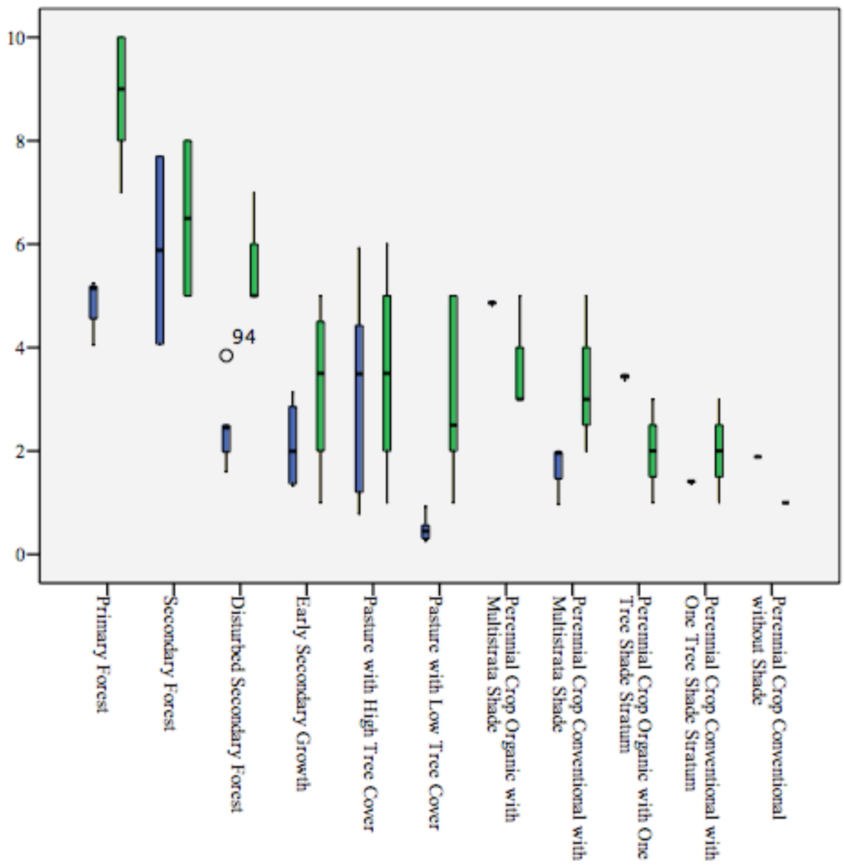


Fig. 3-16: Boxplot of survey (green) and database (blue) biodiversity values for the tropical dry forest.

Tab 3-17: Survey and database means of the biodiversity values for the tropical moist forest on a scale from 0 to 10.

	Mean Survey	Mean Database
Primary forest	9.67	10.00
Secondary forest	6.33	3.40
Disturbed secondary Forest	6	2.46
Early secondary growth	4	0.92
Plantation	3	0.64
Pasture high tree cover	4.75	4.50
Pasture low tree cover	3	0.63
Pasture no tree cover	2	0.00
Perennial crop with multi strata shade trees	5.5	1.95
Perennial crop with shade trees	4	0.75
Annual crop with shade trees	2.5	0.18
Annual crop	3	0.00

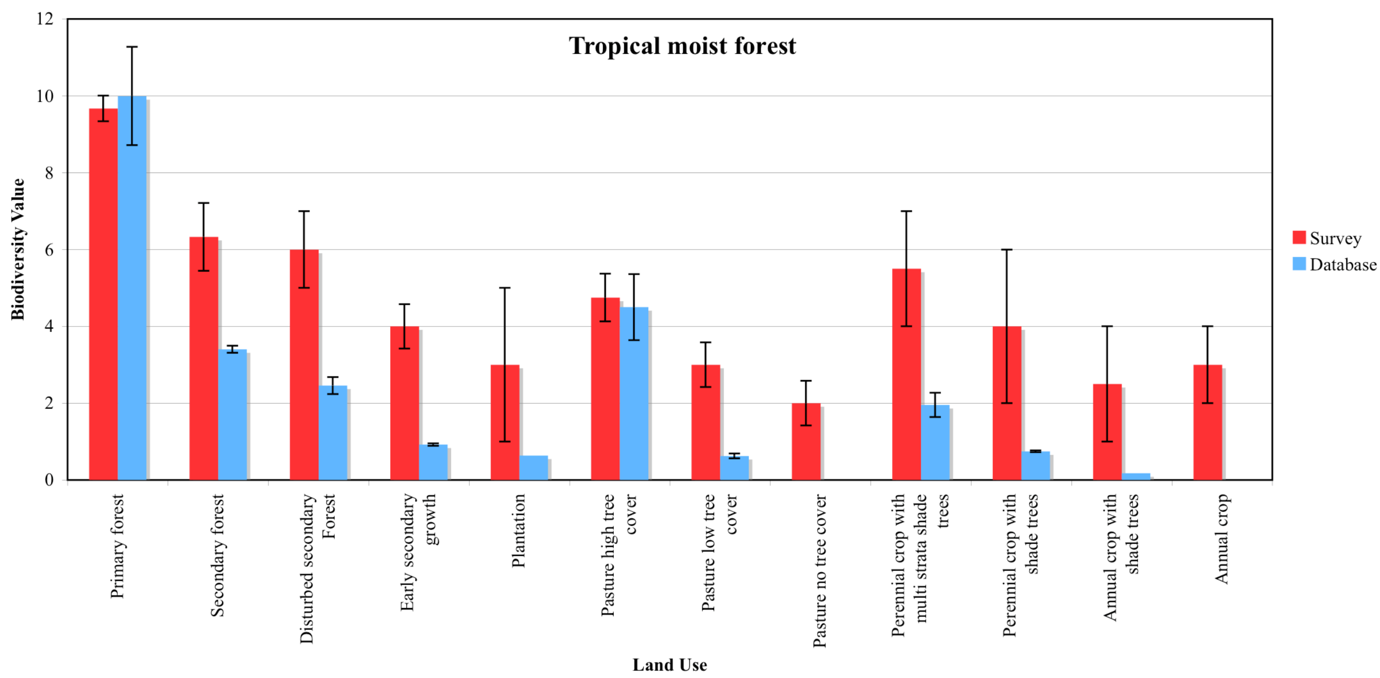


Fig. 3-17: Survey and database results for the tropical moist forest on a scale from 0 to 10.

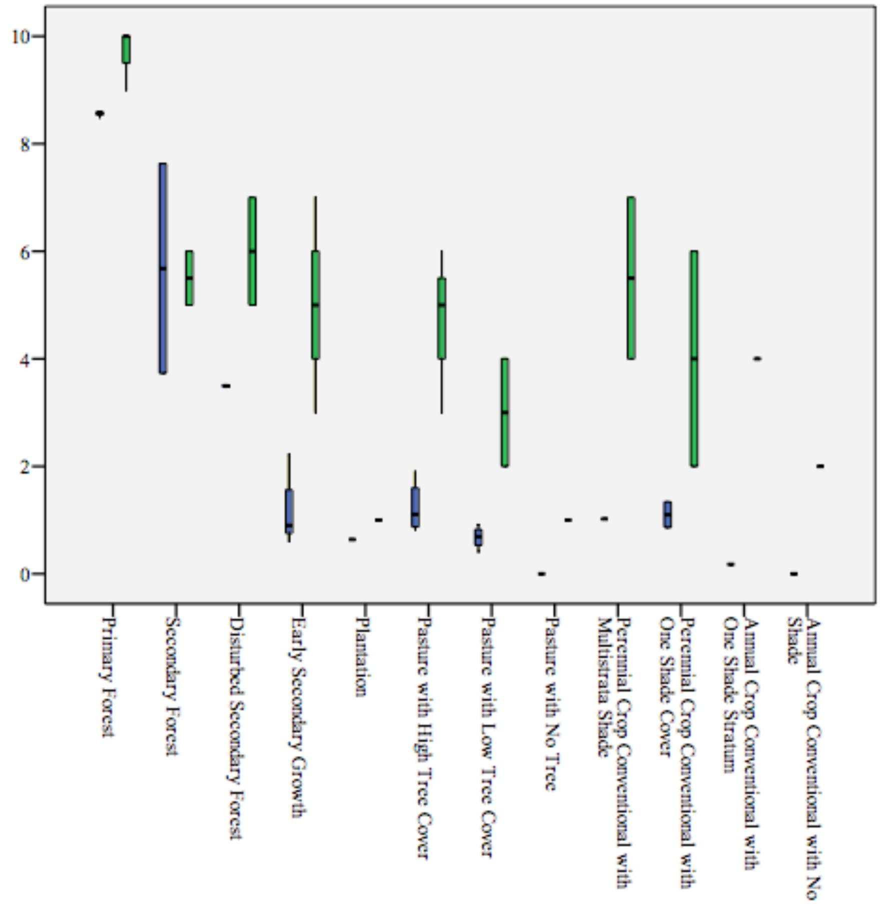


Fig. 3-18: Boxplot of survey (green) and database (blue) biodiversity values for the tropical moist forest.

Tab 3-18: Survey and database means of the biodiversity values for the tropical moist forest on a scale from 0 to 10.

	Mean Survey	**Mean Database**
Primary forest	9	10.00
Secondary forest	6.25	7.25
Disturbed secondary forest	5	4.19
Pasture with high tree cover	3.83	1.63
Pasture with low tree cover	3.6	0.53
Perennial crop, conventional, multistrata shaded	5.75	9.52

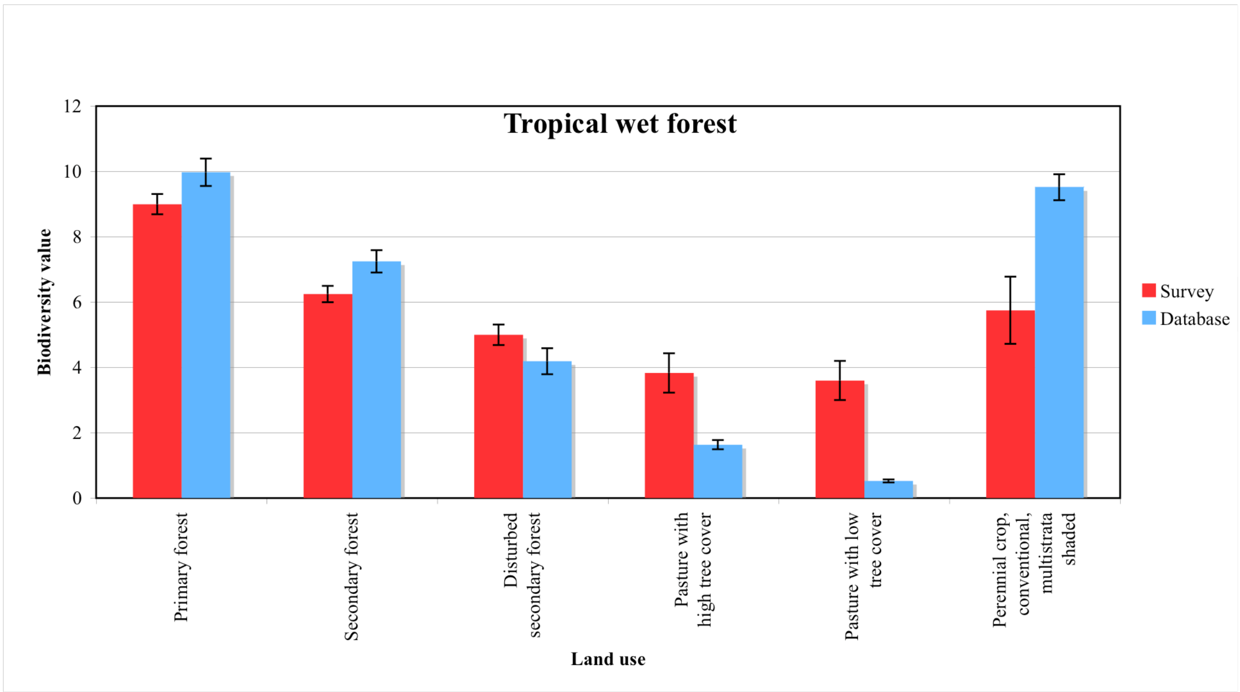


Fig. 3-19: Survey and database results for the tropical wet forest on a 0 to 10 scale.

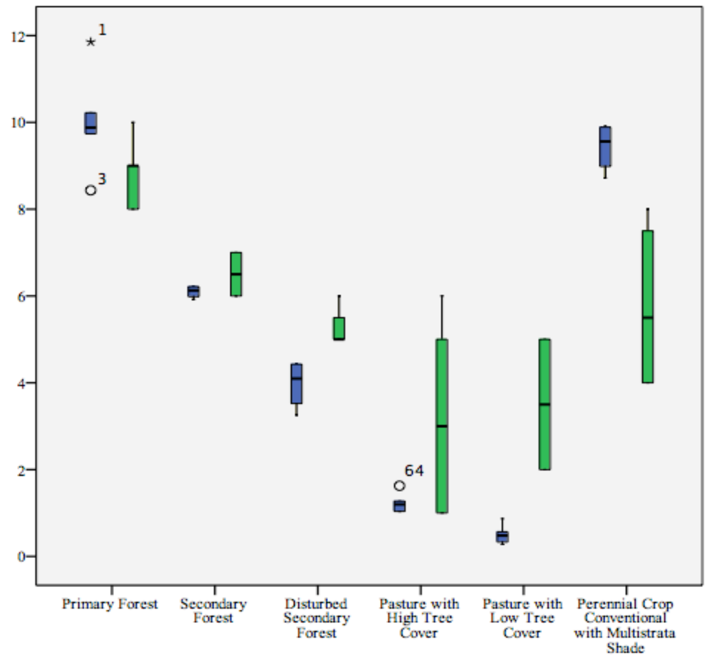


Fig. 3-20: Boxplot of survey (green) and database (blue) biodiversity values for the tropical wet forest.

3.3.2. Statistical comparison between experts' evaluation and meta-analysis data

To statistically test the differences of the biodiversity value between experts' opinion and meta-analysis results I ran a Mann-Whitney U-test. The Mann-Whitney U-test is used for the

comparison of two independent conditions.
The results for the tropical dry forest showed that the means of the categories disturbed secondary forest (p =0.006), pasture with high tree cover (p = 0.036) and pasture with low tree cover (p < 0.001) are significantly different, for the other land cover types one can not confirm this assumption (results are shown in the Appendix).
For the tropical moist forest the results indicate that the biodiversity value between survey and meta-analysis data of secondary forest (p =0.029), disturbed secondary forest (p = 0.026), early secondary growth (p < 0,01), pasture with low tree cover (p < 0.01), perennial crop, conventional, with multistrata shade (p = 0.02) and perennial crop with one shade stratum (p = 0.016) are significantly different (results are shown in the Appendix).
The results of the tropical wet forest show that the biodiversity values of pasture with low tree cover (p < 0.01) and perennial crop, conventional with multistrata shade (p < 0.01) are significantly different between the experts' opinion and the meta-analysis data.

3.4. Ecosystem Damage Potential

For the purpose of LCA I calculated the Ecosystem Damage Potential (EDP) for each land use activity applied in Latin America. I created two separated sets of EDP, one for the experts' evaluations, the second for the meta-analysis's results. I did not derive the EDP using together the two sets of data because they refer to different species groups. Table 3-19 and table 3-20 show the characterization factors for the different land use activities; these values can be used together with period of occupation and area of occupation to calculate the land use impact of a determinate anthropogenic activity.

Tab. 3-19: The Ecosystem Damage Potential (EDP) based on the meta-analysis results.

		Tropical		
Level 1	**Level 2**	**wet**	**moist**	**dry**
Forest	Primary forest	0.00	0.00	0.00
	Secondary forest	0.28	0.66	0.32
	Disturbed secondary forest	0.58	0.75	0.73
	Early secondary growth	-	0.91	0.50
	Plantation	-	0.94	-
	Riparian forest	0.21	0.92	0.59
	Forest + crop	-	-	-0.16
Grassland	Pasture with high tree cover	0.84	0.73	0.63
	Pasture with low tree cover	0.95	0.96	0.89
	Pasture with no tree cover	-	1.00	0.73
Agriculture	Perennial crop, organic, with multistrata cover	-	-	0.58
	Perennial crop, conventional, with multistrata cover	0.05	0.80	0.73
	Perennial crop, organic with one shade stratum	-	-	0.69
	Perennial crop, conventional with one shade stratum	-	0.93	0.74
	Annual crop, conventional, with one shade stratum	-	0.98	-

Level 1	Level 2	Tropical		
		wet	moist	dry
	Perennial crop, conventional	-	-	0.78
	Annual crop, conventional	-	1.00	-

Tab. 3-20: The Ecosystem Damage Potential (EDP) based on the experts' evaluations.

Level 1	Level 2	Tropical			Subtropical		
		dry	moist	wet	dry	moist	wet
Forest	Primary forest, undisturbed	0.00	0.00	0.00	0	0.00	0
	Mature forest	0.05	0.01	0.10	0	0.07	0
	Secondary forest	0.29	0.35	0.36	0	0.14	0.25
	Disturbed secondary forest	0.39	0.38	0.50	0.4	0.35	0.5
	Early secondary growth	0.65	0.59	0.59	0.5	0.38	0.6
	Plantation	0.74	0.59	0.57	0.7	0.62	0.8
Wetland	Tree cover, regularly flooded, fresh water	0.19	0.18	0.43	0.2	0.31	0.3
	Tree cover, regularly flooded, saline water	0.57	0.38	0.63		1.00	0.6
	Regularly flooded shrub/herbaceous cover	0.38	0.08	0.53	0.3	0.52	0.6
Shrublands	Shrub cover, closed-open, no tree cover	0.50	0.44	0.52	0.3	0.48	0.6
	Shrub cover, closed-open, tree cover	0.28	0.23	0.33	0.7	0.33	0.5
	Sparse shrub/herbaceous cover	0.17	0.44	0.63	0.7	0.69	0.8
Grassland	Unused without tree cover	0.49	0.38	0.50	0.7	0.48	0.75
	Unused with natural tree/shrub cover	0.27	0.59	0.67	0.8	0.64	0.7
Pasture	High tree cover, low impact use	0.46	0.49	0.68	0.8	0.59	0.75
	High tree cover, intensive use	0.78	0.54	0.70	0.9	0.69	0.9
	Low tree cover, low impact use	0.51	0.59	0.64	0.7	0.59	0.75
	Low tree cover, intensive use	0.81	0.79	0.72	0.8	0.69	0.8
	No tree cover, low impact use	0.62	0.69	0.73	0.8	0.74	0.85
	No tree cover, intensive use	0.87	0.90	0.83	0.9	0.83	0.95
	Degraded pasture	0.78	0.85	0.90	0.9	0.84	0.95
Agriculture	Perennial or semi-perennial, organic, multi strata tree cover	0.60	0.44	0.38	0.8	0.48	0.7
	Perennial or semi-perennial, conventional, multi strata tree cover	0.64	0.44	0.48	0.9	0.59	0.8
	Perennial or semi-perennial, organic, with one stratum tree cover	0.78	0.54	0.43	0.9	0.59	0.8
	Perennial or semi-perennial culture, conventional, with one stratum tree cover	0.78	0.59	0.45	1	0.69	0.9
	Annual, organic, multi strata tree cover	0.64	0.54	0.48	0.8	0.59	0.65
	Annual, conventional, multi strata tree cover	0.64	0.59	0.58	0.9	0.69	0.85

	Annual, conventional with one stratum tree cover	0.78	0.74	0.53	1	0.79	0.95
	Annual, organic with one stratum tree cover	0.78	0.74	0.50	0.9	0.69	0.85
	Perennial or semi-perennial, organic	0.64	0.69	0.77	0.6	0.53	0.65
	Perennial or semi-perennial, conventional	0.82	0.74	0.80	0.8	0.69	0.8
	Annual, organic	0.89	0.79	0.80	0.9	0.79	0.85
	Annual, conventional	0.89	0.85	0.83	1	0.90	0.95
	Annual, flooded	0.89	0.85	0.83	1	0.95	1
Artificial	Paved road	0.95	1.00	1.00	1	0.97	1
	Unpaved road	0.89	0.95	0.87	1	0.97	0.95
	Rail	0.78	0.90	0.83	1	0.95	1
Urban	Urban, high density	0.95	0.85	0.87	1	0.90	1
	Urban, medium density	0.89	0.69	0.80	1	0.90	0.95
	Urban, low density	0.84	0.59	0.73	1	0.97	0.9
	Urban green areas	0.71	0.54	0.70	0.6	0.72	0.7
Industrial	Industrial, high density	0.95	0.95	0.97	1	0.97	1
	Industrial, medium density	0.92	0.85	0.87	1	0.97	1
	Industrial, low density	0.86	0.74	0.80	1	0.97	1
	Waste dump	0.86	1.00	0.97	1	0.97	1
	Extraction site	0.78	0.95	0.93	1	0.95	1

4. Discussion

The attempt to assess the impact of different land use types on biodiversity in the tropical region of Latin America involves problems concerning the availability of accurate data on species diversity. For this reason I have built my work on the basis of two different analysis and I have compared the results with the aim of finding a compatibility that can be useful for the utilization in the framework of Life Cycle Analysis.

4.1. Meta-analysis results

4.1.1. Gathering of empirical information on species diversity

One of the obstacles encountered during this analysis was the difficulty of finding data regarding the number of vascular plant species that can be found on different land uses. The enormous vegetation diversity found in the tropical region of the American continent is only in part exactly catalogued and studied (Kier et al 2005). In the majority of the publications, the collection of data is limited to only a certain type of vascular plant species or otherwise concentrates on other organisms, for example mammals or insects. In addition, the research studies with a conservational purpose are performed on a restricted number of land use types. As a matter of fact, the gathering of publications concerning urban and industrial areas' biodiversity in the tropical region is very complicated. This lack of empirical information on the total number of plant species is the reason why I performed the meta-analysis on data concerning the group of vascular plants with a d.h.b. of ≥ 10 cm, this group corresponds to tree plant species. Additionally, the information that I collected is restricted only to certain types of land use and does not cover all land use types listed on the GLC2000+ system and ranked in the Life Cycle Assessment. I sampled and evaluated data from thirteen land use types in the tropical dry and moist forest, and seven land use types were sampled for the tropical wet forest.

4.1.2. Meta-analysis results

The meta-analysis results show a similar tendency with respect to the tree species richness for all three Holdridge's life zones; tropical wet, moist and dry forest. To be more precise, the land covers that are closer to the natural condition, and are less influenced by the anthropogenic presence such as the primary forest and the secondary forest, evidence the highest number of tree and shrub species. On the other hand, the land use activities characterized by a greater intensity and environmental impact present the lowest number of species. The monocultures of annual crops with or without shade trees, the monocultures of (semi-) perennial crops without shade and the pasture without trees reveal a lower degree of tree and shrub species diversity per hectare. This fact is clearly supported by the data published on the tropical moist forest zone. An interesting exception to this model is represented by the cultivation of (semi-) perennial crops with multistrata tree shade and a mosaic of natural vegetation, as well as perennial crop plantations that show a high number of tree species per hectare comparable with the primary forest data in the tropical wet forest and higher in the tropical dry forest. This form of land use is very frequent in the tropical regions and normally represents the rustic coffee cultivation or a variant of the agroforestry system. The fact that the data concerning this land use type equals the primary forest value and varies through publications, suggests that the location of the agroforestry practice and the crop cultivated influenced the species number markedly. If the agroforestry is practiced close to a forest there will be a good possibility of a high number/occurrence of species richness. In the case of Latin America,it is recommended that “crop cultivation with multistrata shade” land use type be further specify for clarification of the data.

The impact on the tree species richness determined from cultivation methods (organic or conventional methods) was studied in the tropical dry forest region. The results display an increase in tree species per hectare when organic, instead of conventional, methods are applied. The data is based on the (semi)-perennial crop cultivation with one or more shade strata. Data on the annual crop cultivation are missing in part because the organic cultivation methods are not as widely diffused and studied in the American tropical region as they are in Europe or other regions.

To identify the importance of the role played on biodiversity determination by the bioclimatic conditions characterizing a Holdridge’s life zone, one has to look at the results of the statistical comparison. The statistical tests between the three life zones show that the species numbers for each land use types are significantly different. Apart from the disturbed secondary forest and the perennial conventional cultivations with one shade cover, these two land use types don’t show an F-value greater than 1 but their p-value is not significant. The difference in species number observed for the more natural land covers, such as primary forest or secondary forest is due to the biodiversity level being less influenced by human activity and more influenced by the bioclimatic conditions (that between Holdridge’s life zones are consistently different). For this same reason, the more the human intervention models that the land covers, the more one expects the biodiversity level to be similar even though the bioclimatic characteristics differ. In effect, human intervention is mostly homogeneous around the world. For example, one expects the same level of biodiversity for a perennial culture with one shade stratum situated in a tropical wet region as for a perennial culture with one shade stratum situated in a tropical dry region. In this work, all the data used for carrying out the meta-analysis concern land use activities displaying an intermediate level of land use intensity, for example perennial culture with multiple shade strata or pasture with high tree cover. The data do not concern land use activities with a large anthropogenic impact on the environment, such as urban or industrial areas. Data concerning monocultures are missing for the tropical wet forest and are incomplete for the other two life zones. The land use activities that are characterized by an intermediate level of intensity, may show different plant richness per hectare between life zones because natural components are still present in a certain measure. For example, a pasture with high tree cover can be situated at the edges of a forest displaying vast biodiversity richness in a tropical wet or tropical dry region. For this reason, the statement that the landscape or environmental properties tend to homogenize and to become simple with the increased intensity of land use is not nullified by these data.

Hypothesis 1 supports the fact that with the increase of human intervention, the species diversity decreases. The results of the meta-analysis show that for the vascular plant with d.h.b. of ≥ 10 cm this statement holds at least for the three Holdridge's life zones analyzed. The results also match trends shown by the analysis of the whole vascular plant from Koellner (2001) with regard to the Central European area and from Smith (2008) in respect to the area of Denmark and Malaysia. These two studies showed that the anthropogenic impact and the intensity of this impact are negatively correlated with the biodiversity richness of an area.

4.1.3. The importance of measuring the whole plant diversity

As mentioned previously, the analysis was performed only on tree and shrub species leaving out other important vascular plant categories such as the herbaceous plants. Published data concerning this plant group are rare, as is the information treating the vascular plant species of a region as a whole. However an entire evaluation of the plant biodiversity is essential for the assessment of the impact of land use activities on biodiversity. The works of Lozada (2006), Ospina (2005), Villalobos (2007) and Brown (2000) illustrate patterns that herbaceous biodiversity can assume in relation to different land use activities in the American tropical regions. A high degree of tree biodiversity does not always correspond with an equally high herbaceous diversity. In many cases, the fact that the tree canopy is not so dense because of human intervention allows for the sunlight to penetrate and to reach the lower strata of the vegetation. This procedure is also common in natural forests and occurs when an old tree dies and falls creating a gap in the canopy. Lozada (2006) and Brown(2000) show in their works that the amount of herbaceous species in a landscape dominated by intense human activity is greater than the amount of herbaceous species found in a landscape characterized by lower anthropogenic intervention and by more forest areas. This paradigm doesn't count for the woody plant species that follow the opposite trend. This fact confirms the following statement; a dense tree canopy can block the settlement of herbaceous species. However within the same landscape type the more intense land use activities can result in lower herbaceous species richness. The work of Ospina (2005) concludes that pastures with high intense use host less herbaceous plant species as do pastures with low animal load.

Another fact observed is that not all natural land cover host tree species; a grassland area without tree cover characterized by the absence of human activities will have a score equal to zero in the meta-analysis performed in this work, but in reality its conservation value could be essential for the biodiversity of a region due to the land hosting a lot of herbaceous plant species.

In general, herbaceous plant species don't always follow the same pattern as shrub and tree species, in other words a decrease in tree species diversity does not automatically correspond to a herbaceous species loss. However the intensification of land use activity can contribute to a decrease of herbaceous species diversity in the same way as for the tree and shrub species.

The lack of information concerning plant richness limits the use of the developed results but doesn't minimize the importance of the trees' presence in a certain land use. Previous studies link trees' diversity with the presence of other species important in terms of ecosystem quality. It has been demonstrated that the presence of trees in a fragmented landscape plays an essential role in the conservation of biodiversity. Since they further the connectivity of forest patches and, consequently, the genetic exchange between populations. The presence and diversity of trees is very important, especially in tropical landscapes, because the original land cover of these regions was composed from forest.

4.2. Experts' evaluation

The main problem of the land use assessment in the studied region is the difficulty in creating a complete database with an absolute number of vascular plant species. One method to solve this problem is to analyze the effects of the land use impact using different biodiversity representatives, or to restrict the research to a vascular plant subgroup. Another method is to gather the necessary information through the consultation of experts in the biodiversity field. With these methods in mind, I performed the survey and collected experts' opinions on vascular plant diversity. The results don't refer to the number of absolute species per hectare but are represented on a scale of 0 to 10. Given the complexity of the tropical vegetation, this scale evaluation also simplifies the answering of questions and augments the chance of gaining expert's answers.

4.2.1. Analysis of the experts' evaluations

The experts' answers concern six Holdridge's life zones; tropical wet, moist and dry forest and subtropical wet, moist and dry forest. These are the most present ecosystems types in the studied region, thus they are important for the diversity conservation.

In general the evaluations of all six life zones show a similar pattern that delineates a decrease in the biodiversity level in association with the intensification of the human activities applied in a zone. This pattern reflects the one showed by the meta-analysis data for the vascular plant with d.h.b. of $\geq$ 10 cm.

The experts of all six Holdridge's life zones indicate the undisturbed primary forest as the richest ecosystem in regard to vascular plant biodiversity. This land cover corresponds to the natural cover that occupied the Latin American surface before human intervention, and it represents a hypothetical state, since nowadays there is no area where anthropogenic activities don't have any influence. The other forest types (primary and secondary forest) where human activity is present are also evaluated with a high degree of biodiversity. Also natural wetland covers and shrub lands were indicated by all the experts as land cover types that allow for a rich biodiversity. The statistical tests performed between the tropical wet, moist and dry forest show that the biodiversity's evaluation of these natural covers is similar through life zones. For this reason, one can assume that experts agree with the fact that natural land cover harbors the highest levels of vascular plant biodiversity.

On the other hand, land covers indicated as the poorest in regard to vascular plants richness are artificial surfaces. The territory subjected to this land use is normally totally or partially built up or the ground is chemically polluted. Experts gave a biodiversity evaluation between 0 and 2 for all life zones and evaluated the biodiversity of artificial zones between 0 and 2 for all the six life zones. Urban green areas are an exception within this category and in some cases their biodiversity's level is evaluated as 4 on the scale. The statistical comparison of the artificial zones' evaluations between tropical wet, moist and dry forest also suggests an agreement amongst experts on their low level of biodiversity.

Less homogeneous are experts' evaluations concerning the species richness in grassland and agriculture cover between life zones. Biodiversity values indicate that species diversity is positively influenced by land covered with trees. Despite the tendency of a similar evaluation's pattern, the measure of the biodiversity's value differs within the same land use type, showing that experts don't completely agree on the importance that agriculture and pasture activities have on biodiversity. Often land use activities managed with tree cover, such as pasture with high tree cover or perennial or semi-perennial crop with a multiple shade strata, show a very varied degree of plant diversity. These land use activities can play an important role in relation to concerns about conservation since tree cover, as a landscape element, serves as a connectivity element in a fragmented landscape. The questionnaire differentiates between the levels of intensity of agriculture and cattle breeding activities. In general, the majority of experts indicate as more bio-diverse the low intensity land uses. For example for pasture, a low intensity land use can be understood as meadows with less animal load and no chemical herbicide utilization, otherwise generally recognized as organic methods in the agricultural industry.

The first hypothesis of this work is validated also by experts' evaluations. Indeed they agree that with an increase of anthropogenic land use the biodiversity level of a territory decreases.

4.2.2. Best combination for productivity and biodiversity

Nowadays the conflict between ecosystem preservation and land productivity for economical purposes dominates the decision-making process, thus I formulated the second survey's question for this reason. The experts were asked to express their opinion on this conflict of interests by choosing a combination of three land use activities that could improve both the biodiversity conservation and the productivity.

The experts indicated different types of combinations. Just two of these combinations were selected more than once. The combination of undisturbed primary forest, pasture with high tree cover and low impact use and organic (semi-) perennial crop with multistrata shade cover was indicated as the best solution by four experts; the combination between undisturbed primary forest, primary forest and secondary forest was chosen by two experts. The choice of the undisturbed primary forest is in this case incorrect, because this land cover represents an ideal forest state where no human intervention is applied and the combination with pasture and agriculture would be difficult to achieve.

In general, the experts indicate a combination of forest, pasture and agricultural elements as the best solution for enhancing productivity and preserving biodiversity, pointing out the importance of a mixed landscape. The choice of pasture and agriculture land use implies for the experts the presence of a tree cover, in few cases monoculture or pasture with no tree were chosen as an option. One can deduce that the presence of shade trees positively influences both production and biodiversity.

4.2.3. Vascular plant as a biodiversity indicator

For each region it is possible to choose different types of indicators representing the various levels of biodiversity. In general, the vascular plant species are a good proxy for the entire species diversity and have been already used in other studies that aimed to assess the land use impact.

However experts had to evaluate the effectiveness of this species as a biodiversity representative for the American tropical region. The majority of the experts (60%) completely or nearly (15%) completely agreed with this statement. Moreover empirical studies show how the quantity and diversity of plant species can positively influence the amount of animal species (Harvey et al, 2006; Harvey et Haber 1999). Therefore the use of this group for the assessment of the impact of land use on biodiversity in the framework of LCA is further validated.

4.3. Comparison between experts' evaluation and meta-analysis data

The second hypothesis of this work claims that experts' evaluations reflect the results of the meta-analysis effectuated on empirical data. First of all I have to point out that the comparison can be effectuated only in part because the experts' evaluations consider the whole vascular plant group and the meta-analysis is based on a component of this group. Moreover the results of the meta-analysis had to be transformed on a scale from 0 to 10 in order to enable the comparison.

4.3.1. Direct comparison

As mentioned before, the biodiversity pattern predicted by the first hypothesis has been confirmed by the results of both experiments. To what extent the two results tie in is illustrated statistically.

From the analysis of boxplot and mean's value representations one can visually compare the two data sets for each Holdridge's life zones. The meta-analysis data presents for each land use type extreme values caused by single measurements. These extreme values barely influence the result of boxplots. For this reason the meta-analysis boxplots show some differences in respect to the means' graphical chart, especially for the tropical dry forest data. In general, the curves designed by the meta-analysis data are similar with the curves designed by the survey's data, showing the highest biodiversity in correspondence with forest land cover and decreasing with the enhancement of the land use activity. Although in the meta-analysis data the curve decreases at a greater rate. The statistical comparison for the tropical wet forest suggests that the experts' judgments and the meta-analysis data are significantly different only for the pasture with low tree cover and the conventional perennial crop cultivation with multistrata shade. For tropical moist forest, the only land use that is significantly different is the conventional perennial crop cultivation with one shade stratum. While for tropical dry forest pasture, with low tree cover and disturbed secondary forest, are significantly different. This fact suggests that the experts' opinions can differ with the empirical data in respect to land covers displaying a human activity. However one has to mention that the groups of species analyzed are characterized by a different distribution. The group of vascular plant species evaluated in the survey can have high diversity because herbal species are also present on land with lesser trees. Whereas the group of woody plant species assessed in the meta-analysis show a lower biodiversity degree on the land with lesser trees or without tree cover. This statement can explain the difference between empirical data and experts' evaluations found for some land use types.

In general hypothesis 2, which claims that the experts' evaluations agree to some extent with the meta-analysis results, cannot be rejected, but at the same time it cannot be confirmed because the tree species (the plant group used for the meta-analysis) aren't present in every land use type where vascular plants grow, for example grassland without tree cover. This disparity makes it difficult to integrate both data sets, experts' evaluations and meta-analysis results, to create a unique Ecosystem Damage Potential. This Ecosystem Damage Potential can finally be used for the purpose of Life Cycle Assessment.

4.3.2. Absolute number of species

Four experts provided their estimation on the absolute number of plant species pro hectare for some land use types listed in the classification on Tab. 2-2. The estimations in three cases concern the vascular plant species and in one case the plant species with d.h.b. ≥ 10cm.

The experts indicate forest covers as the species richest ecosystems whereas pastureland and agriculture are signaled as the ecosystems with the lowest diversity. There are no indications regarding the artificial zones. The data does not refer to the same Holdridge's life zones, however the evaluations on the number of species for forest covers and pastureland types overlap to a certain extent. Since these assessments regard the absolute number of vascular plants they cannot be directly compared with the meta-analysis results.

Only the estimation of the fourth expert pertains to the number of plant species with d.h.b. ≥ 10cm and can be used for a direct comparison with the meta-analysis results. In this case the values match the secondary forest in the tropical dry region values, the evaluations concerning primary and disturbed secondary forest do not overlap.

4.4. Problems of whole biodiversity and rare species

Within the assessment of land use impact on biodiversity there are two important points that one has to consider.

One point is the significance that the results obtained on vascular plants covers the whole biodiversity of a region. Different projects within the tropical zone of Latin America aim to collect information about the distribution of animal species and try to analyze the impact of natural land transformation on their habitat. With the landscape fragmentation caused by the increase of agricultural monocultures or by the intensification of cattle farming, the natural habitats of diverse animal species have been destroyed or reduced and the connection between these natural land cover patches has been interrupted. Lenis et al (2007), Tobar Lopez et al (2007), Harvey et al (2006) demonstrate that the land covers characterized by intense use, such as pasture with low tree cover, harbor the lowest species diversity of bats, butterflies, beetles, birds and other animal species. The decrease of biodiversity levels in concomitance with the increase of land use intensity was also emphasized in the publication "Land use on cattle farms" (Murgueito et al, 2003) where the major land use types found in the Central American region have been evaluated according to their importance for the whole biodiversity conservation. According to this study, the primary forest, riparian forest and secondary forest rated the highest biodiversity scores. On the contrary annual crops monocultures and degraded pastures show the lowest species diversity and don't significantly contribute to the conservation concern. The biodiversity ranking of this publication reflects the tendencies shown in both experts' evaluations and meta-analysis results.

The second important point is to estimate the role that one decides to assign to the conservation of endangered endemic species within the framework of Life Cycle Assessment. Which is the most sustainable solution? Using a natural habitat area of an endangered species or exploiting another one that hosts a great number of species?

Even though for the first point one can assume that the use of vascular plants as a reference can solve the problem of assessing the land use impact over the whole biodiversity, the second point still represents a conflict of interests.

4.5. *Output of this project and outlook*

This work aimed to confirm that the increase of land use intensity negatively influences the plant biodiversity in the tropical region of Latin America. It also aimed to gather concrete information on the degree of biodiversity of different land use activities in order to use these data for the purpose of Life Cycle Assessment.

The land use patterns that typically characterize the Latin American territory have been described and catalogued for the purpose of Life Cycle Assessment in order to gather a homogeneous and multifunctional classification that can be used in every continent as demonstrated by comparison with the CORINE+ classification (Appendix 11). For each of these land use activities, experts' evaluations have been collected, and for some of the land use activities data on the number of plants species with d.h.b. ≥ 10cm. The EDP (Ecosystem Damage Potential) characterization factor has been calculated for every land use based on these two sets of information. The EDP can be used while performing a Life Cycle Assessment in order to derive the land use impact of a product or service.

To achieve a more precise analysis and a broader use of the data within the LCA framework, further information on the complex biodiversity characterizing Latin American tropical regions has to be gathered. The data concerns the whole vascular species number living in a determinate land cover type. Presently one has to deepen the research on species diversity concerning all land use activities applied in this region. In this way, one can assess the land use's impact of a specific activity on Latin American biodiversity and compare it with the impact performed by the same activity in another continent, for example Europe, where complete data are already available.

The table in Appendix 10 illustrates the different land cover types according to the developed GLC2000+ system with the number of experts' evaluations or empirical data that are already available for the three Holdridge's life zones; tropical wet, moist and dry forest. This table provides an overview of the acquired information in regards to Latin American tropical regions and provides a starting point for the future collection of data. The final goal is to gather data concerning all land use types within Earth's different bioclimatic zones.

5. Conclusions

This master thesis investigated the impact of land use on biodiversity in the Latin American tropical region in order to gather information that can be used in the framework of Life Cycle Assessment. The hypothesis formulated at the beginning of this work claimed that the intensification of natural land cover depletion in favor of land use committed to human activities, negatively influences the degree of biodiversity within the Latin American region. This phenomenon has already been observed and confirmed globally in other regions where data was evaluated for the purpose of Life Cycle Analysis.

The biodiversity loss is proportional to the intensity of the land use activity in question. Natural or close to natural land cover types harbor the highest level of biodiversity, which decreases with the rise of the anthropogenic land exploitation. This hypothesis has been confirmed by the results of both experiments performed. The meta-analysis on empirical data showed this tendency for the tree species of three tropical life zones and the results of the experts' evaluations sustain this theory in regard to the vascular plant species of six tropical and subtropical life zones. The comparison of the two data sets indicates a concordance even if the two experiments were performed on two different groups of species. The choice to use two different groups was driven by the lack of complete empirical information on vascular plant species. The questionnaire was a means to gain experts' knowledge and thus supply this missing empirical data. Nonetheless the use of vascular plants for the experts' evaluation and only tree plants for the meta-analysis impeded a complete and exhaustive confrontation of the two data sets.

This work shows the degree of biodiversity loss linked with the land utilization and points out the importance of the conservation issue that is often left behind in favor of the benefits of the products of land exploitation, especially in developing countries where the demand of resources and food is increasing. Indeed land use is the human activity displaying the most incisive impact on biodiversity and at the same time strongly influencing other environmental components. For this reason it is important to continue collecting data on species richness according to different land use types. The results of this work set a base for further investigation concerning Latin American regions. The final goal is to have a complete data set for the development of land use characterization factors necessary for performing the Life Cycle Assessment of goods and services.

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Acknowledgement

I would like to thank my supervisor Dr. Thomas Koellner for giving me the possibility of carrying out this master thesis at the NSSI and for his support, his precious help and the interesting discussions.

I would like to thanks Prof. Dr. Patricia Holm for giving me the possibility of realize this project and for correcting and evaluating the master thesis.

Many thanks to Prof. Dr. Stefanie Hellweg and the Ecological System Design group for the possibility of accomplishing a part of my thesis in their institute and for encouraging this work.

Special thanks go to Dr. Fabrice de Clerck, Dr. Muhammad Ibrahim and to all the GAMMA group (Ganaderia y Manejo del Medio Ambiente) for giving me the possibility of collecting data at CATIE and for helping me during my stay in Costa Rica. Thanks for the important scientific input but also for the friendship that all group gave me.

Thanks go to Diego Tobar Lopez and Nei Rios for the interesting conversations and the important clarification concerning the agriculture and pasture methods applied in Latin America.

I would like to thank the experts who compiled the questionnaire. Without their precious contributions I couldn’t carry out this thesis.

Special thanks go to all the people I met in CATIE, for their friendship and the great moments during the three months far away from home.

I would like to thanks also the diplomate students of the NSSI institute for the motivating atmosphere.

Finally a special thank go to my family, for their support and for always motivating me during my study.

Appendix 1

The Earth's 22 land cover categories according to the Global Land Cover 2000 project (Bartholomé E. 2002)

1: Tree cover, broadleaved evergreen, closed to open (>15%)

The main layer consists of broadleaved evergreen closed to open trees. The crown cover is between 100 and 15% (a further sub range can be defined. Closed to Open 100–40%). The height is in the range of >30 - 3m but may be further defined into a smaller range.

2: Tree Cover, broadleaved deciduous, closed (>40%)

The main layer consists of broadleaved deciduous closed to open trees. The crown cover is between 100 and 15% (a further sub range can be defined. Closed to Open 100–40%). The height is in the range of >30 - 3m but may be further defined into a smaller range.

3: Tree cover, broadleaved deciduous, open (15-40%)

The main layer consists of broadleaved deciduous woodland. The crown cover is between (70-60) and (20-10)%. The openness of the vegetation may be further specified. The height is in the range of >30 -3m but may be further defined into a smaller range.

4: Tree cover, needle-leaved evergreen, closed to open (>15%)

The main layer consists of needle-leaved evergreen closed to open trees. The crown cover is between 100 and 15% (a further sub range can be defined – Closed to Open 100–40%). The height is in the range of >30 - 3m but may be further defined into a smaller range.

5: Tree cover, needle-leaved deciduous, closed to open (>15%)

The main layer consists of needle-leaved deciduous closed to open trees. The crown cover is between 100 and 15% (a further sub range can be defined. Closed to Open 100–40%). The height is in the range of >30 - 3m but may be further defined into a smaller range.

6: Tree cover, mixed leaf type closed to open (>15%)

The main layer consists of broadleaved closed to open trees. The crown cover is between 100 and 15% (a further sub range can be defined. Closed to Open 100–40%). The height is in the range of >30 - 3m but may be further defined into a smaller range. // The main layer consists of needle-leaved closed to open trees. The crown cover is between 100 and 15% (a further sub range can be defined – Closed to Open 100–40%). The height is in the range of >30 - 3m but may be further defined into a smaller range.

7: Tree cover, closed to open (>15%), regularly flooded, fresh or brackish water: Swamp Forests

The main layer consists of closed to open broadleaved evergreen woodland on permanently flooded land. The crown cover is between 100 and 15%. The openness of the vegetation may be further specified. The height is in the range of >30 - 3m but may be further defined into a smaller range.

The main layer consists of closed to open broadleaved evergreen woodland on permanently flooded land. The crown cover is between 100 and 15%. The openness of the vegetation may be further specified. The height is in the range of >30 - 3m but may be further defined into a smaller range.

The main layer consists of broadleaved evergreen closed to open woodland on seasonally flooded land. The crown cover is between 100 and 15% (a further sub range can be defined – Closed to Open 100–40%). The openness of the vegetation may be further specified. The height is in the range of >30 - 3m but may be further defined into a smaller range.

The main layer consists of broadleaved evergreen closed to open woodland on seasonally flooded land. The crown cover is between 100 and 15% (a further sub range can be defined. Closed to Open 100–40%). The openness of the vegetation may be further specified. The height is in the range of >30 - 3m but may be further defined into a smaller range.

8: Tree cover, closed to open (>15%), regularly flooded, saline water: Mangrove Forests

The main layer consists of broadleaved evergreen closed trees on permanently flooded land. The crown cover is more than (70-60)%. The height is in the range of >30 - 3m but may be further defined into a smaller range.

9: Mosaic of tree cover and other natural vegetation (crop component possible)

The main layer consists of closed trees. The crown cover is more than (70-60)%. The height is in the range of >30 - 3m but may be further defined into a smaller range. Primarily vegetated areas containing more than four percent vegetation during at least two months a year. The environment is influenced by the edaphic substratum. The vegetative cover is characterized by the presence of (semi)-natural vegetation which species composition, its environmental and ecological processes are indistinguishable from, or in a process of achieving, its undisturbed state. The vegetative cover is not artificial and does not need to be managed nor maintained.

Primarily vegetated areas containing more than four percent vegetation during at least two months a year. The environment is influenced by the edaphic substratum. The vegetative cover is characterized by the removal of the (semi)-natural vegetation and replacement with a vegetative cover resulting from human activities. This cover is artificial and requires maintenance. It is grown with the intention to be managed and/or (partly) harvested at the end of the growing season. Before or after harvest there may be a period without vegetative cover.

10: Tree Cover, burnt (mainly boreal forests)

The main layer consists of closed to open trees. The crown cover is between 100 and 15% (a further sub range can be defined – Closed to Open 100–40%).

11: Shrub cover, closed to open (>15%) , evergreen(broadleaved or needle-leaved)

The main layer consists of broadleaved evergreen closed to open thicket. The crown cover is between 100 and 15% (a further sub range can be defined – Closed to Open 100–40%). The height is in the range of 5 - 0.3m but may be further defined into a smaller range.

The main layer consists of needle-leaved evergreen closed to open thicket. The crown cover is between 100 and 15% (a further sub range can be defined – Closed to Open 100–40%). The height is in the range of 5 - 0.3m but may be further defined into a smaller range.

12: Shrub cover, closed to open (>15%), deciduous (broadleaved)

The main layer consists of broadleaved deciduous closed to open thicket. The crown cover is between 100 and 15% (a further sub range can be defined – Closed to Open 100–40%). The height is in the range of 5 - 0.3m but may be further defined into a smaller range.

13: Herbaceous cover, closed to open (>15%)

The main layer consists of closed to open herbaceous vegetation. The crown cover is between 100 and 15% (a further sub range can be defined – Closed to Open 100–40%). The height is in the range of 3 - 0.03m but may be further defined into a smaller range.

14: Sparse Herbaceous or sparse Shrub cover

The main layer consists of sparse herbaceous vegetation. The crown cover is between (20-10) and 1%. The sparseness of the vegetation may be further specified.

The main layer consists of sparse shrubs. The crown cover is between (20-10) and 1%. The sparseness of the vegetation may be further specified.

15: Regularly flooded (> 2 month) Shrub or Herbaceous cover, closed to The main layer consists of closed to open shrubs on permanently flooded land. The crown cover is between 100 and 15% (a further sub range can be defined – Closed to Open 100–40%). The openness of the vegetation may be further specified. The height is in the range of 5 - 0.3m but may be further defined into a smaller range.

The main layer consists of closed to open shrubs on permanently flooded land. The crown cover is between 100 and 15% (a further sub range can be defined – Closed to Open 100–40%). The openness of the vegetation may be further specified. The height is in the range of 5 - 0.3m but may be further defined into a smaller range.

The main layer consists of closed to open shrubs on seasonally flooded land. The crown cover is

between 100 and 15% (a further sub range can be defined – Closed to Open 100–40%). The openness of the vegetation may be further specified. The height is in the range of 5 - 0.3m but may be further defined into a smaller range.
The main layer consists of closed to open shrubs on seasonally flooded land. The crown cover is between 100 and 15% (a further sub range can be defined – Closed to Open 100–40%). The openness of the vegetation may be further specified. The height is in the range of 5 - 0.3m but may be further defined into a smaller range.
The main layer consists of closed to open herbaceous vegetation on permanently flooded land. The crown cover is between 100 and 15% (a further sub range can be defined – Closed to Open 100–40%). The height is in the range of 3 - 0.03m but may be further defined into a smaller range.
The main layer consists of closed to open herbaceous vegetation on permanently flooded land. The crown cover is between 100 and 15% (a further sub range can be defined – Closed to Open 100–40%). The height is in the range of 3 - 0.03m but may be further defined into a smaller range.
The main layer consists of closed herbaceous vegetation on seasonally flooded land. The crown cover is more than (70-60)%. The height is in the range of 3 - 0.03m but may be further defined into a smaller range.
The main layer consists of closed herbaceous vegetation on seasonally flooded land. The crown cover is more than (70-60)%. The height is in the range of 3 - 0.03m but may be further defined into a smaller range.

16: Cropland (upland crops or inundated/ flooded crops as e.g. rice)

Primarily vegetated areas containing more than four percent vegetation during at least two months a year. The environment is influenced by the edaphic substratum. The vegetative cover is characterized by the removal of the (semi)-natural vegetation and replacement with a vegetative cover resulting from human activities. This cover is artificial and requires maintenance. It is grown with the intention to be managed and/or (partly) harvested at the end of the growing season. Before or after harvest there may be a period without vegetative cover.
Primarily vegetated areas containing more than four percent vegetation during at least two months a year. The environment is significantly influenced by the presence of water over extensive periods of time, i.e. water is present for more than three months a year and when water is present less than three months a year, it is present 75 percent of the flooding time. The vegetative cover is characterized by the removal of the (semi)-natural vegetation and replacement with a vegetative cover resulting from human activities. This cover is artificial and requires maintenance. It is grown with the intention to be managed and/or (partly) harvested at the end of the growing season. Before or after harvest there may be a period without vegetative cover.

17: Mosaic of Cropland / Tree cover/ Other Natural Vegetation

Primarily vegetated areas containing more than four percent vegetation during at least two months a year. The environment is influenced by the edaphic substratum. The vegetative cover is characterized by the removal of the (semi)-natural vegetation and replacement with a vegetative cover resulting from human activities. This cover is artificial and requires maintenance. It is grown with the intention to be managed and/or (partly) harvested at the end of the growing season. Before or after harvest there may be a period without vegetative cover. / The main layer consists of closed to open trees. The crown cover is between 100 and 15% (a further sub range can be defined – Closed to Open 100–40%). The height is in the range of 30-3m and is not further defined.

Primarily vegetated areas containing more than four percent vegetation during at least two months a year. The environment is influenced by the edaphic substratum. The vegetative cover is characterized by the presence of (semi)-natural vegetation which species composition, its environmental and ecological processes are indistinguishable from, or in a process of achieving, its undisturbed state. The vegetative cover is not artificial and does not need to be managed nor maintained.

18: Mosaic of Cropland / Shrub or Herbaceous cover

Primarily vegetated areas containing more than four percent vegetation during at least two months a year. The environment is influenced by the edaphic substratum. The vegetative cover is characterized by the removal of the (semi)-natural vegetation and replacement with a vegetative cover resulting from human activities. This cover is artificial and requires maintenance. It is grown with the intention to be managed and/or (partly) harvested at the end of the growing season. Before or after harvest there may be a period without vegetative cover. The main layer consists of closed to open shrub land. The crown cover is between 100 and 15% (a further sub range can be defined – Closed to Open 100–40%).

The main layer consists of closed to open herbaceous vegetation. The crown cover is between 100 and 15% (a further sub range can be defined – Closed to Open 100–40%).

19: Barre Area

Primarily non-vegetated areas containing less than four percent vegetation during at least 10 months a year. The environment is influenced by the edaphic substratum. The cover is natural. Included are areas like bare rock and sands.

20: Water Bodies (natural or artificial)

The land cover consists of artificial water bodies. A further specification can be made in flowing or standing water.

The land cover consists of natural water bodies. A further specification can be made in flowing or standing water.

21: Snow or Ice (natural or artificial)

The land cover consists of artificial snow.

The land cover consists of artificial ice. A further specification can be made in moving or stationary ice.

The land cover consists of snow.

The land cover consists of ice. A further specification can be made in moving or stationary ice.

22: Urban area(s)

The land cover consists of built up area(s)

Appendix 2

The Appendix 2 shows the land use description insert in the questionnaire of the international survey.

Level 1	Level 2	Description
Forest		
	Primary forest, undisturbed	Primary forest, undisturbed, no trace of human intervention, with over 80% canopy cover. Forest fragments of different sizes.
	Mature forest	Mature forest undisturbed during the last thirty years, with over 80% canopy cover. Fragments of different sizes.
	Secondary forest	Native forest managed moderately over the past 3 decades. Forest fragment of different sizes.
	Disturbed secondary forest	Native forest that has been disturbed over the past 3 decades, either through high level of timber extraction, harvest of non-timber resources, hunting or partial felling. Forest fragments of different sizes.
	Early secondary growth	Native vegetation at different successional stages with tree height under 5 m.
	Plantation	Artificially planted tree cover, need maintenance, mainly for timber production. More than 500 trees per hectare
Wetland		
	Tree cover, regularly flooded, fresh water	The main layer consists of closed to open broadleaved evergreen woodland on permanently flooded land. The crown cover is between 100 and 15%.
	Tree cover, regularly flooded, saline water	The main layer consists of closed to open broadleaved evergreen woodland on permanently flooded land. The crown cover is between 100 and 15%.'Mangrove forest' (daily variation of water level).
	Regularly flooded shrub/herbaceous cover	The main layer consists of closed to open shrubs or grass on permanently or seasonally flooded land. May include bogs and sparse tree layer.
Shrubland		
	Shrub cover, closed-open, no tree cover	The main layer consists of closed to open thicket. The crown cover is between 100 and 40% The height is in the range of 5 - 0.3m. There is no tree cover.
	Shrub cover, closed-open, tree cover	The main layer consists of closed to open thicket. The crown cover is between 100 and 40% The height is in the range of 5 - 0.3m. There are scattered trees.
	Sparse shrub/herbaceous cover	The shrub vegetation is sparse, 20 - 1% cover.
Grassland		

Level 1	Level 2	Description
	Unused without tree cover	Grassland with no tree cover. The area isn't used for livestock feeding.
	Unused with natural tree/shrub cover	grassland with scattered trees or shrubs. The area isn't used for livestock feeding.
	No tree cover, low impact use	Pastures managed with low impact on the vegetation, rotation of the livestock, no over-grassing, use of chemical products in low concentration. With no tree cover.
	No tree cover, intensive use	Pasture managed with a clearly damaging impact on plant richness (fertilizing, herbicide application, over-grassing) with no tree cover.
	Low tree cover, low impact use	Pastures managed with low impact on the vegetation, rotation of the livestock, no over-grassing, use of chemical products in low concentration. Tree cover: 30 or less than 30 trees pro hectare.
	Low tree cover, intensive use	Pasture managed with a clearly damaging impact on plant richness (fertilizing, herbicide application, over-grassing). Tree cover: 30 or less than 30 trees pro hectare.
	High tree cover, low impact use	Pastures managed with low impact on the vegetation, rotation of the livestock, no over-grassing, use of chemical products in low concentration. Tree cover: more than 30 trees pro hectare.
	High tree cover, intensive use	Pasture managed with a clearly damaging impact on plant richness (fertilizing, herbicide application, over-grassing). Tree cover: more than 30 trees pro hectare.
	Degraded pasture	Pasture with less than 50% cover of desirable grasses and shrubs. Minimal presence of trees and shrubs. May show evident erosion.
Agriculture		
	Perennial or semi-perennial, conventional	Perennial or semi-perennial crops (orchard, coffee, berry plantations). Cultivated with the use of chemical and synthetic fertilizers and pesticides.
	Perennial or semi-perennial, organic	Perennial or semi-perennial crops (orchard, coffee, berry plantations). Cultivated without the use of chemical and synthetic fertilizers and pesticides.
	Annual, conventional	Short term crops, fewer than 12 months or 12 months, includes basic grains such as corn and beans, vegetables (tomatoes and others) and tubers (potatoes). Cultivated with the use of chemical and synthetic fertilizers and pesticides.
	Annual, organic	Short term crops, fewer than 12 months or 12 months, includes basic grains such as corn and beans, vegetables (tomatoes and others) and tubers (potatoes). Cultivated without the use of chemical and synthetic fertilizers and pesticides.
	Annual, flooded	Herbaceous crops, less than 3m high, flooded during cultivation period, e.g. rice fields

Level 1	Level 2	Description
	Annual, conventional with one stratum tree cover	The main culture is a short term crops (under 12 months or 12 months) includes basic grains such as corn and beans, vegetables (tomatoes and others) and tubers (potatoes), cultivated with the use of chemical and synthetic fertilizers and pesticides. The fruit or shade tree/shrub cover is composed of one canopy layer.
	Annual, organic with one stratum tree cover	The main culture is a short term crops (under 12 months or 12 months) includes basic grains such as corn and beans, vegetables (tomatoes and others) and tubers (potatoes). Cultivated without the use of chemical and synthetic fertilizers and pesticides. The fruit or shade tree/shrub cover is composed of one canopy layer.
	Annual, conventional, multistrata tree cover	The main culture is a short term crops (under 12 months or 12 months) includes basic grains such as corn and beans, vegetables (tomatoes and others) and tubers (potatoes). The fruit or shade tree/shrub cover is composed of various canopy layers.
	Annual, organic, multistrata tree cover	The main culture is a short term crops (under 12 months or 12 months) includes basic grains such as corn and beans, vegetables (tomatoes and others) and tubers (potatoes), cultivated without the use of chemical and synthetic fertilizers and pesticides. The fruit or shade tree/shrub cover is composed of various canopy layers.
	Perennial or semi-perennial culture, conventional, with one stratum tree cover	The main culture is a perennial or semi-perennial crop (for example coffee plantation), cultivated without the use of chemical and synthetic fertilizers and pesticides. This main culture is grown together with a fruit or shade tree/shrub cover composed of one canopy layer.
	Perennial or semi-perennial, organic, with one stratum tree cover	The main culture is a perennial or semi-perennial crop (for example coffee plantation), cultivated without the use of chemical and synthetic fertilizers and pesticides. This main culture is grown together with a fruit or shade tree/shrub cover composed of one canopy layer.
	Perennial or semi-perennial, conventional, multistrata tree cover	The main culture is a perennial or semi-perennial crop (for example coffee plantation), cultivated with the use of chemical and synthetic fertilizers and pesticides. This main culture is grown together with a fruit or shade tree/shrub cover composed of various canopy layers.
	Perennial or semi-perennial, organic, multistrata tree cover	The main culture is a perennial or semi-perennial crop (for example coffee plantation), cultivated without the use of chemical and synthetic fertilizers and pesticides. This main culture is grown together with a fruit or shade tree/shrub cover composed of various canopy layers.

Level 1	Level 2	Description
Artificial Areas		
	Paved road	
	Unpaved road	
	Rail	
Urban	Urban, high density	More than 75% of the total surface consists of impervious surface(s), City centre (almost totally sealed)
	Urban, medium density	50-75% of the total surface consists of impervious surface(s); Business and residential districts with green areas and gardens.
	Urban, low density	15-50% of the total surface consists of impervious surface(s); Rural settlement with buildings, streets and gardens, Sport facilities (soccer pitch with building), Urban fallow, remains of demolished houses are removed and areas are leveled (non-use).
	Urban green areas	Parks and Green Urban Areas.
Industrial	Industrial, high density	More than 75% of the total surface consists of impervious surface(s), Industrial, high proportion of sealed area; open soil, sometime contaminated with chemicals. Airports, Goods depots, Stations, Seaport areas.
	Industrial, medium density	50-75% of the total surface consists of impervious surface(s), Industrial area with medium proportion of sealed area, open soil, sometimes contaminated with chemicals. Areas with remains of industrial buildings, Deposits.
	Industrial, low density	15-50% of the total surface consists of impervious surface(s), industrial fallow, areas with remains of industrial buildings.
	Waste dump	Deposits of rubble, gravel and sand.
	Extraction site	Areas with open-pit extraction of industrial minerals or other materials.

Appendix 3

Appendix 3 is a Word version of the original Excel questionnaire for the experts' survey.

Impact of Land Use on Vascular Plant Richness

The goal of this expert survey is to gather knowledge on the impact of land use on plant species diversity. The information will be used to develop impact factors concerning biodiversity in the framework of Life Cycle Assessment (LCA). LCA is a method to compile a complete inventory of the environmental impact of products and services through all stages of their life cycle. This tool is used as a support for environmental decision-making by industries, governmental and non-governmental organizations. LCA allows to compare the environmental performances of products and services in order to choose the most sustainable alternative or enables to optimize their life cycle with respect to the environment. The life cycle of a product or service includes production of raw material, manufacturing, transportation, product or service use and waste treatment and has various categories of environmental impacts (http://lcinitiative. unep.fr). Land use is one of these impact categories included in the LCA. Human land use activities, like agriculture, industry, timber production influence biodiversity richness. Previous studies (Koellner 2003; Koellner et Scholz 2007) based on meta-analysis developed a method for the assessment of the land use impact on biodiversity in the framework of LCA. With this survey we aim to collect expert evaluations on this problem at global scale. As a representative for the biodiversity richness of each type of land cover we select vascular plant species. Vascular plants are an important component of most ecosystems because they represent the first tropic level and serve as a habitat.

With vascular plants or *tracheophytes* we refer to all the plants with lignified tissues for conducting water, minerals, and photosynthetic products. They include **ferns, clubmosses, angiosperms and gymnosperms.**

For classifying the different land covers at a global scale the Global Land Cover Classification 2000 (GLC2000) Project (Bartholomé E., Belward S., 2005) developed by the European Community is taken as a reference. The GLC2000 divides the earth surface into 22 main categories, these categories are grouped into 9 domains according to characteristics like the presence of vegetation, water and human activity. We further developed this classification system in order to gather the differences between land using as references the classification developed by T. Koellner (PhD Thesis *Land use in product life cycle and its consequences for ecosystem quality,* 2001) and the classification developed by E. Murgueitio et al. (*Land use on cattle farms,* 2003) for the GEF project.

SURVEY'S STRUCTURE

The survey is structured as a list of different land uses. The definition of each land uses is written as comment that will appear by touching the upper-right corner of each box.
This survey was developed thinking on a global scale. Therefore it's possible that land covers that don't exist in your research area are listed in the classification system. You can insert your estimation for the ecosystems or land uses on which you work or which exists in your research region and choose to insert the estimation for the other land uses. Join to the survey's page you find the list of the life zones described by L. Holdridge (L. Holdridge Life zone ecology, 1967) in the page "Life zones". Please specify the life zone that you will use as reference to fill out this questionnaire:

____

1. **Can you evaluate on a scale from 0 to 10 the richness of vascular plant species present in the different land uses listed below? 10 represents the land use with the highest level of species number in the life zone you use as a reference, 0 the lowest level and 5 the intermediate level.**

Once inserted the values you can visualize the results on the graphic in the page figure 1.
Optional: Can you indicate how many vascular plant species would expect to find on average pro hectare for the land uses where you do your field work. Can you indicate the minimum and maximum of your evaluation?

			Optional:		
Level 1	**Level 2**	**Value**	**Nr. of species**	**Min**	**Max**
Forest					
	Primary forest, undisturbed				
	Mature forest				
	Secondary forest				
	Disturbed secondary forest				
	Early secondary growth				
	Plantation				
Wetland					
	Tree cover, regularly flooded, fresh water				
	Tree cover, regularly flooded, saline water				
	Regularly flooded shrub/herbaceous cover				

Shrubland					
	Shrub cover, closed-open, no tree cover				
	Shrub cover, closed-open, tree cover				
	Sparse shrub/herbaceous cover				
Grassland					
	Unused without tree cover				
	Unused with natural tree/shrub cover				
Pasture					
	No tree cover, low impact use				
	No tree cover, intensive use				
	Low tree cover, low impact use				
	Low tree cover, intensive use				
	High tree cover, low impact use				
	High tree cover, intensive use				
	Degraded pasture				
Agriculture					
Monoculture					
	Perennial or semi-perennial, conventional				
	Perennial or semi-perennial, organic				
	Annual, conventional				
	Annual, organic				
	Annual, flooded				
Policulture					
	Annual, conventional with one stratum tree cover				
	Annual, organic with one stratum tree cover				
	Annual, conventional, multistrata tree cover				
	Annual, organic, multistrata tree cover				
	Perennial or semi-perennial culture, conventional, with one stratum tree cover				
	Perennial or semi-perennial, organic, with one stratum tree cover				
	Perennial or semi-perennial, conventional, multistrata tree cover				
	Perennial or semi-perennial, organic, multistrata tree cover				
Artificial					
	Paved road				
	Unpaved road				
	Rail				
Urban	Urban, high density				

	Urban, medium density				
	Urban, low density				
	Urban green areas				
Industrial	Industrial, high density				
	Industrial, medium density				
	Industrial, low density				
	Waste dump				
	Extraction site				

2. Can you indicate according to your experience, which would be the best combination of three land uses (listed below) favorable to conserve the biodiversity of a farm and at the same time improve its productivity?

Level 1	**Level 2**	**Insert X for the 3 land uses**
Forest		
	Primary forest, undisturbed	
	Mature forest	
	Secondary forest	
	Disturbed secondary forest	
	Early secondary growth	
	Plantation	
	Primary forest, undisturbed	
	Mature forest	
Grassland		
Pasture		
	No tree cover, low impact use	
	No tree cover, intensive use	
	Low tree cover, low impact use	
	Low tree cover, intensive use	
	High tree cover, low impact use	
	High tree cover, intensive use	
	Degraded pasture	
Agriculture		
Monoculture		
	Perennial or semi-perennial, conventional	
	Perennial or semi-perennial, organic	
	Annual, conventional	
	Annual, organic	
Policulture		
	Annual, conventional with one stratum tree cover	
	Annual, organic with one stratum tree	

	cover	
	Annual, conventional, multistrata tree cover	
	Annual, organic, multistrata tree cover	
	Perennial or semi-perennial culture, conventional, with one stratum tree cover	
	Perennial or semi-perennial, organic, with one stratum tree cover	
	Perennial or semi-perennial, conventional, multistrata tree cover	
	Perennial or semi-perennial, organic, multistrata tree cover	

METHODOLOGICAL QUESTION
In order to improve the survey and to perform a better analysis of the results we need your opinion about some methodological aspects.

1. Do you think that the number of vascular plant species is a good indicator for the biodiversity richness?

2. Which is your personal opinion about this survey?

3. Would you suggest some modifications of the land use classification?

PERSONAL QUESTION

In order to compare answers from different participants, we need further information about you. Note that the answers to this section are for statistical analysis only and that your name and the name of your institution will be treated confidentially.

1. Which is your area of study?

2. How would you define the type of work you do?

Basic research

Applied research

Decision marker

Other; specify:

3. What type of organization do you work for?

Research institute

Env. NGO's

Gov. agencies

Other; specify:

4. What is your knowledge about (1=very good/ 7=no knowledge):

a. Biodiversity

b. LCA

c. Land Use

5. For how long have you been working with plant biodiversity or land use?

Land use

Biodiversity

6. Countries where you do most of your field work:

7. Type of ecosystem where you do most of your field work:

Forest

Wetland

Shrubland

Grassland

Agriculture

Artificial

We would be very thankful if you could suggest a database or sources where we can find information about vascular plant richness concerning the area where you work.

We gratefully thank you for your participation and your support

Appendix 4

Appendix 4 shows the names of the experts that filled out the questionnaire.

A = agriculture; F = forestry; C = conservation; S = systematic are the four work's fields according to whom I selected the experts.

Expert's name	Expert's institution	Country	Field
Carlos Astorga	CATIE	Costa rica	A
Dr. Gerardo Avalos	Universidad Nacional Escuela de biologia	Costa Rica	F
Dr. Mario Barroso	Coservation org. Brazil	Brazil	C
Dr. Zoraida Calle	CIPAV	Colombia	C
Dr. George Camargo	Conservação Internacional Center for Applied Biodiversity Science (CABS)	Brazil	C
Prof. Robin Chazdon	Organizacion para estudios tropicales-Universidad de Connecticut	Costa Rica	F
Dr. Andreas Ebert	CATIE	Costa Rica	F
Ms Wendy Francesconi	University of florida	Latin America	F
Dr. Mauro Galetti	UNESP - Departamento de Ecologia	Brazil	A
Rudy Guzman	Centro Amazonico de Desarrollo Forestal	Bolivia	F
Ing. William Hernández Castro	UNA Instituo de sevicio Forestale	Costa Rica	F
Dr. Miranda Marcio	IAPAR	Brazil	A
Dr. Sandro Menezes	Conservation org.	Brazil	C
Víctor H. Meza	UNA Instituto de servicio forestale	Costa Rica	F
Dr. Carlos O. Morales	Universidad Nacional de Costa Rica Escuela de biologia	Costa Rica	S
Albert Morera Beita	UNA Instituto de sevicio forestale	Costa Rica	F
Prof. Dr. Nalini Nadkarni	The Evergreen State College	Central America	F
Dr. Ricardo Russo	EARTH	Latino America	A
Dr. Ruperto Quesada Monge	Instituto tecnico de Costa Rica Centro de Investigación en Integración Bosque Industria (CIIBI)	Costa Rica	F
Dr. George Edmund Pilz	Escuela Agrícola Panamericana el Zamorano.	Honduras	C

Appendix 5

Results of the ANOVA test for the survey answers concerning the Holdridge's life zones tropical wet, moist and dry forest

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Primary Forest Undisturbed	Between Groups	1.269	2	.635	.846	.458
	Within Groups	7.500	10	.750		
	Total	8.769	12			
Mature Forest	Between Groups	1.700	2	.850	.908	.432
	Within Groups	10.300	11	.936		
	Total	12.000	13			
Secondary Forest	Between Groups	.133	2	.067	.047	.955
	Within Groups	12.867	9	1.430		
	Total	13.000	11			
Disturbed Secondary Forest	Between Groups	.777	2	.389	.523	.612
	Within Groups	5.950	8	.744		
	Total	6.727	10			
Early Secondary Growth	Between Groups	3.750	2	1.875	1.316	.311
	Within Groups	14.250	10	1.425		
	Total	18.000	12			
Plantation	Between Groups	17.395	2	8.698	1.226	.331
	Within Groups	78.033	11	7.094		
	Total	95.429	13			
Wetland Fresh Water	Between Groups	5.333	2	2.667	.385	.699
	Within Groups	34.667	5	6.933		
	Total	40.000	7			
Wetland Salt Water	Between Groups	3.429	2	1.714	.343	.729
	Within Groups	20.000	4	5.000		
	Total	23.429	6			
Wetland Sparse Vegetation	Between Groups	10.583	2	5.292	.842	.484
	Within Groups	31.417	5	6.283		
	Total	42.000	7			
Shurbland No Tree Cover	Between Groups	.933	2	.467	.234	.797
	Within Groups	13.967	7	1.995		
	Total	14.900	9			
Shrubland Tree Cover	Between Groups	1.633	2	.817	.462	.648
	Within Groups	12.367	7	1.767		

	Total	14.000	9			
Shrubland with Sparse Shrub Cover	Between Groups	25.233	2	12.617	2.663	.138
	Within Groups	33.167	7	4.738		
	Total	58.400	9			
Grassland No Tree Cover No Use	Between Groups	2.086	2	1.043	.176	.842
	Within Groups	47.550	8	5.944		
	Total	49.636	10			
Grassland Tree Cover No Use	Between Groups	31.417	2	15.708	4.779	.039
	Within Groups	29.583	9	3.287		
	Total	61.000	11			
Pastureland No Tree Cover Low Use	Between Groups	.556	2	.278	.238	.795
	Within Groups	7.000	6	1.167		
	Total	7.556	8			
Pastureland No Tree Cover Intense Use	Between Groups	.583	2	.292	.512	.623
	Within Groups	3.417	6	.569		
	Total	4.000	8			
Pastureland Low Tree Cover Low Use	Between Groups	.600	2	.300	.233	.798
	Within Groups	9.000	7	1.286		
	Total	9.600	9			
Pastureland Low Tree Cover Intense Use	Between Groups	3.350	2	1.675	1.737	.244
	Within Groups	6.750	7	.964		
	Total	10.100	9			
Pastureland High Tree Cover Low Use	Between Groups	5.556	2	2.778	1.562	.284
	Within Groups	10.667	6	1.778		
	Total	16.222	8			
Pastureland High Tree Cover Intense Use	Between Groups	8.389	2	4.194	1.228	.357
	Within Groups	20.500	6	3.417		
	Total	28.889	8			
Pasture Degraded	Between Groups	2.000	2	1.000	.560	.595
	Within Groups	12.500	7	1.786		
	Total	14.500	9			
Perennial Crop Conventional	Between Groups	.833	2	.417	1.786	.260
	Within Groups	1.167	5	.233		
	Total	2.000	7			
Perennial Crop Organic	Between Groups	1.542	2	.771	.526	.621
	Within Groups	7.333	5	1.467		
	Total	8.875	7			
Annual Crop Conventional	Between Groups	.708	2	.354	1.518	.305
	Within Groups	1.167	5	.233		
	Total	1.875	7			
Annual Crop Organic	Between Groups	1.875	2	.938	2.344	.191
	Within Groups	2.000	5	.400		
	Total	3.875	7			

Annual Crop Flooded	Between Groups	.708	2	.354	1.518	.305
	Within Groups	1.167	5	.233		
	Total	1.875	7			
Annual Crop Conventional One Shade Stratum	Between Groups	9.639	2	4.819	1.061	.403
	Within Groups	27.250	6	4.542		
	Total	36.889	8			
Annual Crop Organic One Shade Stratum	Between Groups	19.250	2	9.625	1.490	.298
	Within Groups	38.750	6	6.458		
	Total	58.000	8			
Annual Crop Conventional Multi Shade Strata	Between Groups	4.889	2	2.444	.449	.658
	Within Groups	32.667	6	5.444		
	Total	37.556	8			
Annual Crop Organic Multi Shade Strata	Between Groups	3.042	2	1.521	.383	.700
	Within Groups	19.833	5	3.967		
	Total	22.875	7			
Perennial Crop Conventional One Shade Stratum	Between Groups	18.139	2	9.069	3.249	.111
	Within Groups	16.750	6	2.792		
	Total	34.889	8			
Perennial Crop Organic One Shade Stratum	Between Groups	21.389	2	10.694	5.580	.043
	Within Groups	11.500	6	1.917		
	Total	32.889	8			
Perennial Crop Conventional Multi Shade Stratum	Between Groups	10.972	2	5.486	1.502	.296
	Within Groups	21.917	6	3.653		
	Total	32.889	8			
Perennial Crop Organic Multi Shade Stratum	Between Groups	11.639	2	5.819	2.194	.193
	Within Groups	15.917	6	2.653		
	Total	27.556	8			
Paved Road	Between Groups	.556	2	.278	1.667	.266
	Within Groups	1.000	6	.167		
	Total	1.556	8			
Unpaved Road	Between Groups	.833	2	.417	.349	.719
	Within Groups	7.167	6	1.194		
	Total	8.000	8			
Rail	Between Groups	1.333	2	.667	.194	.829
	Within Groups	20.667	6	3.444		
	Total	22.000	8			
Urban High Intensity	Between Groups	3.222	2	1.611	1.261	.349
	Within Groups	7.667	6	1.278		
	Total	10.889	8			
Urban Medium Intensity	Between Groups	5.556	2	2.778	1.667	.266
	Within Groups	10.000	6	1.667		
	Total	15.556	8			
Urban Low Intensity	Between Groups	8.556	2	4.278	1.638	.271

	Within Groups	15.667	6	2.611		
	Total	24.222	8			
Urban	Between Groups	4.333	2	2.167	1.182	.380
	Within Groups	9.167	5	1.833		
	Total	13.500	7			
Industrial High Intensity	Between Groups	.056	2	.028	.077	.927
	Within Groups	2.167	6	.361		
	Total	2.222	8			
Industrial Medium Intensity	Between Groups	1.833	2	.917	1.320	.335
	Within Groups	4.167	6	.694		
	Total	6.000	8			
Industrial Low Intensity	Between Groups	2.306	2	1.153	.954	.437
	Within Groups	7.250	6	1.208		
	Total	9.556	8			
Waste	Between Groups	2.542	2	1.271	4.766	.069
	Within Groups	1.333	5	.267		
	Total	3.875	7			
Extraction	Between Groups	4.389	2	2.194	.767	.505
	Within Groups	17.167	6	2.861		
	Total	21.556	8			

Results of the Post Hoc Bonferoni test for the data of the biodiversity survey. The Bonferoni test was performed between the categories tropical wet forest, tropical moist forest and tropical dry forest.

Multiple Comparisons

Bonferroni

Dependent Variable	(I) LIFE ZONES	(J) LIFE ZONES	Mean Dif. (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Primary Forest Undisturbed	tropical dry forest	tropical moist forest	-.50000	.61237	1.000	-2.2576	1.2576
		Tropical wet forest	-.75000	.58095	.677	-2.4174	.9174
	tropical moist forest	tropical dry forest	.50000	.61237	1.000	-1.2576	2.2576
		Tropical wet forest	-.25000	.58095	1.000	-1.9174	1.4174
	Tropical wet forest	tropical dry forest	.75000	.58095	.677	-.9174	2.4174
		tropical moist forest	.25000	.58095	1.000	-1.4174	1.9174
Mature Forest	tropical dry forest	tropical moist forest	-.86667	.70668	.737	-2.8595	1.1262
		Tropical wet forest	-.03333	.58595	1.000	-1.6857	1.6191
	tropical moist forest	tropical dry forest	.86667	.70668	.737	-1.1262	2.8595
		Tropical wet forest	.83333	.68424	.746	-1.0962	2.7629
	Tropical wet forest	tropical dry forest	.03333	.58595	1.000	-1.6191	1.6857
		tropical moist forest	-.83333	.68424	.746	-2.7629	1.0962
Secondary Forest	tropical dry forest	tropical moist forest	.26667	.87319	1.000	-2.2947	2.8280
		Tropical wet forest	.10000	.80208	1.000	-2.2528	2.4528
	tropical moist forest	tropical dry forest	-.26667	.87319	1.000	-2.8280	2.2947
		Tropical wet forest	-.16667	.91321	1.000	-2.8454	2.5121
	Tropical wet forest	tropical dry forest	-.10000	.80208	1.000	-2.4528	2.2528
		tropical moist forest	.16667	.91321	1.000	-2.5121	2.8454
Disturbed Secondary Forest	tropical dry forest	tropical moist forest	-.40000	.72154	1.000	-2.5760	1.7760
		Tropical wet forest	.35000	.57852	1.000	-1.3947	2.0947
	tropical moist forest	tropical dry forest	.40000	.72154	1.000	-1.7760	2.5760
		Tropical wet forest	.75000	.74687	1.000	-1.5024	3.0024
	Tropical wet forest	tropical dry forest	-.35000	.57852	1.000	-2.0947	1.3947
		tropical moist forest	-.75000	.74687	1.000	-3.0024	1.5024
Early Secondary Growth	tropical dry forest	tropical moist forest	-.75000	.91173	1.000	-3.3667	1.8667
		Tropical wet forest	-1.25000	.77055	.407	-3.4615	.9615
	tropical moist forest	tropical dry forest	.75000	.91173	1.000	-1.8667	3.3667
		Tropical wet forest	-.50000	.84410	1.000	-2.9226	1.9226
	Tropical wet forest	tropical dry forest	1.25000	.77055	.407	-.9615	3.4615
		tropical moist forest	.50000	.84410	1.000	-1.9226	2.9226
Plantation	tropical dry forest	tropical moist forest	-.60000	1.94511	1.000	-6.0853	4.8853
		Tropical wet forest	-2.43333	1.61280	.479	-6.9815	2.1148
	tropical	tropical dry forest	.60000	1.94511	1.000	-4.8853	6.0853

		Tropical wet forest	-1.83333	1.88334	1.000	-7.1444	3.4777
	Tropical wet forest	tropical dry forest	2.43333	1.61280	.479	-2.1148	6.9815
		tropical moist forest	1.83333	1.88334	1.000	-3.4777	7.1444
Shurbland No Tree	tropical dry forest	tropical moist forest	-.83333	1.28946	1.000	-4.8662	3.1995
		Tropical wet forest	-.53333	1.03157	1.000	-3.7596	2.6929
	tropical moist forest	tropical dry forest	.83333	1.28946	1.000	-3.1995	4.8662
		Tropical wet forest	.30000	1.18181	1.000	-3.3962	3.9962
	Tropical wet forest	tropical dry forest	.53333	1.03157	1.000	-2.6929	3.7596
		tropical moist forest	-.30000	1.18181	1.000	-3.9962	3.3962
Shrubland Tree Cover	tropical dry forest	tropical moist forest	-.16667	1.21335	1.000	-3.9615	3.6282
		Tropical wet forest	.73333	.97068	1.000	-2.3025	3.7692
	tropical moist forest	tropical dry forest	.16667	1.21335	1.000	-3.6282	3.9615
		Tropical wet forest	.90000	1.11206	1.000	-2.5780	4.3780
	Tropical wet forest	tropical dry forest	-.73333	.97068	1.000	-3.7692	2.3025
		tropical moist forest	-.90000	1.11206	1.000	-4.3780	2.5780
Sparse Shrub Cover	tropical dry forest	tropical moist forest	2.16667	1.98706	.935	-4.0480	8.3813
		Tropical wet forest	3.66667	1.58965	.163	-1.3050	8.6384
	tropical moist forest	tropical dry forest	-2.16667	1.98706	.935	-8.3813	4.0480
		Tropical wet forest	1.50000	1.82117	1.000	-4.1958	7.1958
	Tropical wet forest	tropical dry forest	-3.66667	1.58965	.163	-8.6384	1.3050
		tropical moist forest	-1.50000	1.82117	1.000	-7.1958	4.1958
Grassland No Tree Cover No Use	tropical dry forest	tropical moist forest	-1.25000	2.11135	1.000	-7.6173	5.1173
		Tropical wet forest	-.45000	1.63545	1.000	-5.3821	4.4821
	tropical moist forest	tropical dry forest	1.25000	2.11135	1.000	-5.1173	7.6173
		Tropical wet forest	.80000	2.03976	1.000	-5.3514	6.9514
	Tropical wet forest	tropical dry forest	.45000	1.63545	1.000	-4.4821	5.3821
		tropical moist forest	-.80000	2.03976	1.000	-6.9514	5.3514
Grassland Tree Cover No Use	tropical dry forest	tropical moist forest	2.75000	1.57012	.341	-1.8557	7.3557
		Tropical wet forest	3.58333*	1.17030	.041	.1505	7.0162
	tropical moist forest	tropical dry forest	-2.75000	1.57012	.341	-7.3557	1.8557
		Tropical wet forest	.83333	1.48032	1.000	-3.5089	5.1756
	Tropical wet forest	tropical dry forest	-3.58333*	1.17030	.041	-7.0162	-.1505
		tropical moist forest	-.83333	1.48032	1.000	-5.1756	3.5089
Pastureland No Tree Cover Low Use	tropical dry forest	tropical moist forest	.50000	.93541	1.000	-2.5751	3.5751
		Tropical wet forest	.50000	.82496	1.000	-2.2120	3.2120
	tropical moist forest	tropical dry forest	-.50000	.93541	1.000	-3.5751	2.5751
		Tropical wet forest	.00000	.98601	1.000	-3.2415	3.2415
	Tropical wet forest	tropical dry forest	-.50000	.82496	1.000	-3.2120	2.2120
		tropical moist forest	.00000	.98601	1.000	-3.2415	3.2415
Pastureland No Tree Cover Intense Use	tropical dry forest	tropical moist forest	.25000	.65352	1.000	-1.8984	2.3984
		Tropical wet forest	-.41667	.57635	1.000	-2.3114	1.4780
	tropical	tropical dry forest	-.25000	.65352	1.000	-2.3984	1.8984

		Tropical wet forest	-.66667	.68887	1.000	-2.9313	1.5980
	Tropical wet forest	tropical dry forest	.41667	.57635	1.000	-1.4780	2.3114
		tropical moist forest	.66667	.68887	1.000	-1.5980	2.9313
Pastureland Low Tree Cover Low Use	tropical dry forest	tropical moist forest	.50000	.98198	1.000	-2.5712	3.5712
		Tropical wet forest	.50000	.80178	1.000	-2.0076	3.0076
	tropical moist forest	tropical dry forest	-.50000	.98198	1.000	-3.5712	2.5712
		Tropical wet forest	.00000	.98198	1.000	-3.0712	3.0712
	Tropical wet forest	tropical dry forest	-.50000	.80178	1.000	-3.0076	2.0076
		tropical moist forest	.00000	.98198	1.000	-3.0712	3.0712
Pastureland Low Tree Cover Intense Use	tropical dry forest	tropical moist forest	-.25000	.85042	1.000	-2.9097	2.4097
		Tropical wet forest	-1.25000	.69437	.345	-3.4217	.9217
	tropical moist forest	tropical dry forest	.25000	.85042	1.000	-2.4097	2.9097
		Tropical wet forest	-1.00000	.85042	.834	-3.6597	1.6597
	Tropical wet forest	tropical dry forest	1.25000	.69437	.345	-.9217	3.4217
		tropical moist forest	1.00000	.85042	.834	-1.6597	3.6597
Pastureland High Tree Cover Low Use	tropical dry forest	tropical moist forest	.00000	1.15470	1.000	-3.7960	3.7960
		Tropical wet forest	1.66667	1.01835	.458	-1.6811	5.0144
	tropical moist forest	tropical dry forest	.00000	1.15470	1.000	-3.7960	3.7960
		Tropical wet forest	1.66667	1.21716	.660	-2.3347	5.6680
	Tropical wet forest	tropical dry forest	-1.66667	1.01835	.458	-5.0144	1.6811
		tropical moist forest	-1.66667	1.21716	.660	-5.6680	2.3347
Pastureland High Tree Cover Intense Use	tropical dry forest	tropical moist forest	-2.50000	1.60078	.508	-7.7625	2.7625
		Tropical wet forest	-1.00000	1.41176	1.000	-5.6411	3.6411
	tropical moist forest	tropical dry forest	2.50000	1.60078	.508	-2.7625	7.7625
		Tropical wet forest	1.50000	1.68737	1.000	-4.0472	7.0472
	Tropical wet forest	tropical dry forest	1.00000	1.41176	1.000	-3.6411	5.6411
		tropical moist forest	-1.50000	1.68737	1.000	-7.0472	4.0472
Pasture Degraded	tropical dry forest	tropical moist forest	.50000	1.15728	1.000	-3.1194	4.1194
		Tropical wet forest	1.00000	.94491	.975	-1.9553	3.9553
	tropical moist forest	tropical dry forest	-.50000	1.15728	1.000	-4.1194	3.1194
		Tropical wet forest	.50000	1.15728	1.000	-3.1194	4.1194
	Tropical wet forest	tropical dry forest	-1.00000	.94491	.975	-3.9553	1.9553
		tropical moist forest	-.50000	1.15728	1.000	-4.1194	3.1194
Perennial Crop Conventional	tropical dry forest	tropical moist forest	-.83333	.44096	.352	-2.3917	.7251
		Tropical wet forest	-.33333	.39441	1.000	-1.7272	1.0605
	tropical moist forest	tropical dry forest	.83333	.44096	.352	-.7251	2.3917
		Tropical wet forest	.50000	.44096	.925	-1.0584	2.0584
	Tropical wet forest	tropical dry forest	.33333	.39441	1.000	-1.0605	1.7272
		tropical moist forest	-.50000	.44096	.925	-2.0584	1.0584
Perennial Crop Organic	tropical dry forest	tropical moist forest	.33333	1.10554	1.000	-3.5738	4.2404
		Tropical wet forest	1.00000	.98883	1.000	-2.4946	4.4946
	tropical moist forest	tropical dry forest	-.33333	1.10554	1.000	-4.2404	3.5738
		Tropical wet forest	.66667	1.10554	1.000	-3.2404	4.5738

	Tropical wet forest	tropical dry forest	-1.00000	.98883	1.000	-4.4946	2.4946
		tropical moist forest	-.66667	1.10554	1.000	-4.5738	3.2404
Annual Crop Concentional	tropical dry forest	tropical moist forest	-.50000	.44096	.925	-2.0584	1.0584
		Tropical wet forest	-.66667	.39441	.455	-2.0605	.7272
	tropical moist forest	tropical dry forest	.50000	.44096	.925	-1.0584	2.0584
		Tropical wet forest	-.16667	.44096	1.000	-1.7251	1.3917
	Tropical wet forest	tropical dry forest	.66667	.39441	.455	-.7272	2.0605
		tropical moist forest	.16667	.44096	1.000	-1.3917	1.7251
Annual Crop Organic	tropical dry forest	tropical moist forest	-1.00000	.57735	.431	-3.0404	1.0404
		Tropical wet forest	-1.00000	.51640	.332	-2.8250	.8250
	tropical moist forest	tropical dry forest	1.00000	.57735	.431	-1.0404	3.0404
		Tropical wet forest	.00000	.57735	1.000	-2.0404	2.0404
	Tropical wet forest	tropical dry forest	1.00000	.51640	.332	-.8250	2.8250
		tropical moist forest	.00000	.57735	1.000	-2.0404	2.0404
Annual Crop Flooded	tropical dry forest	tropical moist forest	-.50000	.44096	.925	-2.0584	1.0584
		Tropical wet forest	-.66667	.39441	.455	-2.0605	.7272
	tropical moist forest	tropical dry forest	.50000	.44096	.925	-1.0584	2.0584
		Tropical wet forest	-.16667	.44096	1.000	-1.7251	1.3917
	Tropical wet forest	tropical dry forest	.66667	.39441	.455	-.7272	2.0605
		tropical moist forest	.16667	.44096	1.000	-1.3917	1.7251
Annual Crop Conventional One Shade Stratum	tropical dry forest	tropical moist forest	-.50000	1.94544	1.000	-6.8955	5.8955
		Tropical wet forest	-2.25000	1.62767	.648	-7.6009	3.1009
	tropical moist forest	tropical dry forest	.50000	1.94544	1.000	-5.8955	6.8955
		Tropical wet forest	-1.75000	1.84560	1.000	-7.8173	4.3173
	Tropical wet forest	tropical dry forest	2.25000	1.62767	.648	-3.1009	7.6009
		tropical moist forest	1.75000	1.84560	1.000	-4.3173	7.8173
Annual Crop Organic One Shade Stratum	tropical dry forest	tropical moist forest	-1.00000	2.31990	1.000	-8.6266	6.6266
		Tropical wet forest	-3.25000	1.94097	.435	-9.6308	3.1308
	tropical moist forest	tropical dry forest	1.00000	2.31990	1.000	-6.6266	8.6266
		Tropical wet forest	-2.25000	2.20085	1.000	-9.4852	4.9852
	Tropical wet forest	tropical dry forest	3.25000	1.94097	.435	-3.1308	9.6308
		tropical moist forest	2.25000	2.20085	1.000	-4.9852	9.4852
Annual Crop Conventional Multi Shade Strata	tropical dry forest	tropical moist forest	-.66667	2.13003	1.000	-7.6691	6.3357
		Tropical wet forest	-1.66667	1.78211	1.000	-7.5253	4.1919
	tropical moist forest	tropical dry forest	.66667	2.13003	1.000	-6.3357	7.6691
		Tropical wet forest	-1.00000	2.02073	1.000	-7.6430	5.6430
	Tropical wet forest	tropical dry forest	1.66667	1.78211	1.000	-4.1919	7.5253
		tropical moist forest	1.00000	2.02073	1.000	-5.6430	7.6430
Annual Crop Organic Multi Shade Strata	tropical dry forest	tropical moist forest	-1.16667	1.81812	1.000	-7.5921	5.2588
		Tropical wet forest	-1.33333	1.62617	1.000	-7.0804	4.4137
	tropical moist forest	tropical dry forest	1.16667	1.81812	1.000	-5.2588	7.5921
		Tropical wet forest	-.16667	1.81812	1.000	-6.5921	6.2588
	Tropical wet	tropical dry forest	1.33333	1.62617	1.000	-4.4137	7.0804

		tropical moist forest	.16667	1.81812	1.000	-6.2588	6.5921
Perennial Crop Conventional One Shade Stratum	tropical dry forest	tropical moist forest	-2.00000	1.52525	.713	-7.0142	3.0142
		Tropical wet forest	-3.25000	1.27612	.131	-7.4452	.9452
	tropical moist forest	tropical dry forest	2.00000	1.52525	.713	-3.0142	7.0142
		Tropical wet forest	-1.25000	1.44698	1.000	-6.0069	3.5069
	Tropical wet forest	tropical dry forest	3.25000	1.27612	.131	-.9452	7.4452
		tropical moist forest	1.25000	1.44698	1.000	-3.5069	6.0069
Perennial Crop Organic One Shade Stratum	tropical dry forest	tropical moist forest	-2.50000	1.26381	.286	-6.6547	1.6547
		Tropical wet forest	-3.50000*	1.05738	.049	-6.9761	-.0239
	tropical moist forest	tropical dry forest	2.50000	1.26381	.286	-1.6547	6.6547
		Tropical wet forest	-1.00000	1.19896	1.000	-4.9415	2.9415
	Tropical wet forest	tropical dry forest	3.50000*	1.05738	.049	.0239	6.9761
		tropical moist forest	1.00000	1.19896	1.000	-2.9415	4.9415
Perennial Crop Conventional Multi Shade Stratum	tropical dry forest	tropical moist forest	-2.16667	1.74470	.782	-7.9023	3.5690
		Tropical wet forest	-2.41667	1.45972	.447	-7.2154	2.3821
	tropical moist forest	tropical dry forest	2.16667	1.74470	.782	-3.5690	7.9023
		Tropical wet forest	-.25000	1.65517	1.000	-5.6913	5.1913
	Tropical wet forest	tropical dry forest	2.41667	1.45972	.447	-2.3821	7.2154
		tropical moist forest	.25000	1.65517	1.000	-5.1913	5.6913
Perennial Crop Organic Multi Shade Stratum	tropical dry forest	tropical moist forest	-1.83333	1.48682	.791	-6.7212	3.0545
		Tropical wet forest	-2.58333	1.24397	.249	-6.6728	1.5062
	tropical moist forest	tropical dry forest	1.83333	1.48682	.791	-3.0545	6.7212
		Tropical wet forest	-.75000	1.41053	1.000	-5.3870	3.8870
	Tropical wet forest	tropical dry forest	2.58333	1.24397	.249	-1.5062	6.6728
		tropical moist forest	.75000	1.41053	1.000	-3.8870	5.3870
Paved Road	tropical dry forest	tropical moist forest	.50000	.35355	.621	-.6623	1.6623
		Tropical wet forest	.50000	.31180	.480	-.5250	1.5250
	tropical moist forest	tropical dry forest	-.50000	.35355	.621	-1.6623	.6623
		Tropical wet forest	.00000	.37268	1.000	-1.2252	1.2252
	Tropical wet forest	tropical dry forest	-.50000	.31180	.480	-1.5250	.5250
		tropical moist forest	.00000	.37268	1.000	-1.2252	1.2252
Unpaved Road	tropical dry forest	tropical moist forest	.50000	.94648	1.000	-2.6115	3.6115
		Tropical wet forest	-.33333	.83472	1.000	-3.0774	2.4108
	tropical moist forest	tropical dry forest	-.50000	.94648	1.000	-3.6115	2.6115
		Tropical wet forest	-.83333	.99768	1.000	-4.1132	2.4465
	Tropical wet forest	tropical dry forest	.33333	.83472	1.000	-2.4108	3.0774
		tropical moist forest	.83333	.99768	1.000	-2.4465	4.1132
Rail	tropical dry forest	tropical moist forest	1.00000	1.60728	1.000	-4.2838	6.2838
		Tropical wet forest	.33333	1.41748	1.000	-4.3266	4.9932
	tropical moist forest	tropical dry forest	-1.00000	1.60728	1.000	-6.2838	4.2838
		Tropical wet forest	-.66667	1.69422	1.000	-6.2363	4.9030
	Tropical wet	tropical dry forest	-.33333	1.41748	1.000	-4.9932	4.3266

		tropical moist forest	.66667	1.69422	1.000	-4.9030	6.2363
Urban High Intensity	tropical dry forest	tropical moist forest	-1.50000	.97895	.529	-4.7182	1.7182
		Tropical wet forest	-.83333	.86335	1.000	-3.6716	2.0049
	tropical moist forest	tropical dry forest	1.50000	.97895	.529	-1.7182	4.7182
		Tropical wet forest	.66667	1.03190	1.000	-2.7257	4.0590
	Tropical wet forest	tropical dry forest	.83333	.86335	1.000	-2.0049	3.6716
		tropical moist forest	-.66667	1.03190	1.000	-4.0590	2.7257
Urban Medium Intensity	tropical dry forest	tropical moist forest	-2.00000	1.11803	.372	-5.6755	1.6755
		Tropical wet forest	-1.00000	.98601	1.000	-4.2415	2.2415
	tropical moist forest	tropical dry forest	2.00000	1.11803	.372	-1.6755	5.6755
		Tropical wet forest	1.00000	1.17851	1.000	-2.8743	4.8743
	Tropical wet forest	tropical dry forest	1.00000	.98601	1.000	-2.2415	4.2415
		tropical moist forest	-1.00000	1.17851	1.000	-4.8743	2.8743
Urban Low Intensity	tropical dry forest	tropical moist forest	-2.50000	1.39940	.373	-7.1005	2.1005
		Tropical wet forest	-1.16667	1.23416	1.000	-5.2239	2.8906
	tropical moist forest	tropical dry forest	2.50000	1.39940	.373	-2.1005	7.1005
		Tropical wet forest	1.33333	1.47510	1.000	-3.5160	6.1827
	Tropical wet forest	tropical dry forest	1.16667	1.23416	1.000	-2.8906	5.2239
		tropical moist forest	-1.33333	1.47510	1.000	-6.1827	3.5160
Urban Green	tropical dry forest	tropical moist forest	-1.83333	1.23603	.594	-6.2016	2.5349
		Tropical wet forest	-.33333	1.10554	1.000	-4.2404	3.5738
	tropical moist forest	tropical dry forest	1.83333	1.23603	.594	-2.5349	6.2016
		Tropical wet forest	1.50000	1.23603	.837	-2.8683	5.8683
	Tropical wet forest	tropical dry forest	.33333	1.10554	1.000	-3.5738	4.2404
		tropical moist forest	-1.50000	1.23603	.837	-5.8683	2.8683
Industrial High Intensity	tropical dry forest	tropical moist forest	.00000	.52042	1.000	-1.7108	1.7108
		Tropical wet forest	.16667	.45896	1.000	-1.3422	1.6755
	tropical moist forest	tropical dry forest	.00000	.52042	1.000	-1.7108	1.7108
		Tropical wet forest	.16667	.54857	1.000	-1.6367	1.9701
	Tropical wet forest	tropical dry forest	-.16667	.45896	1.000	-1.6755	1.3422
		tropical moist forest	-.16667	.54857	1.000	-1.9701	1.6367
Industrial Medium Intensity	tropical dry forest	tropical moist forest	-1.00000	.72169	.645	-3.3725	1.3725
		Tropical wet forest	-.83333	.63647	.715	-2.9257	1.2590
	tropical moist forest	tropical dry forest	1.00000	.72169	.645	-1.3725	3.3725
		Tropical wet forest	.16667	.76073	1.000	-2.3342	2.6675
	Tropical wet forest	tropical dry forest	.83333	.63647	.715	-1.2590	2.9257
		tropical moist forest	-.16667	.76073	1.000	-2.6675	2.3342
Industrial Low Intensity	tropical dry forest	tropical moist forest	-1.25000	.95197	.711	-4.3796	1.8796
		Tropical wet forest	-.75000	.83956	1.000	-3.5100	2.0100
	tropical moist forest	tropical dry forest	1.25000	.95197	.711	-1.8796	4.3796
		Tropical wet forest	.50000	1.00347	1.000	-2.7989	3.7989
	Tropical wet forest	tropical dry forest	.75000	.83956	1.000	-2.0100	3.5100
		tropical moist forest	-.50000	1.00347	1.000	-3.7989	2.7989

Waste	tropical dry forest	tropical moist forest	1.33333	.47140	.110	-.3327	2.9993
		Tropical wet forest	1.00000	.42164	.191	-.4901	2.4901
	tropical moist forest	tropical dry forest	-1.33333	.47140	.110	-2.9993	.3327
		Tropical wet forest	-.33333	.47140	1.000	-1.9993	1.3327
	Tropical wet forest	tropical dry forest	-1.00000	.42164	.191	-2.4901	.4901
		tropical moist forest	.33333	.47140	1.000	-1.3327	1.9993
Extraction	tropical dry forest	tropical moist forest	1.50000	1.46487	1.000	-3.3157	6.3157
		Tropical wet forest	1.33333	1.29189	1.000	-2.9137	5.5804
	tropical moist forest	tropical dry forest	-1.50000	1.46487	1.000	-6.3157	3.3157
		Tropical wet forest	-.16667	1.54410	1.000	-5.2428	4.9095
	Tropical wet forest	tropical dry forest	-1.33333	1.29189	1.000	-5.5804	2.9137
		tropical moist forest	.16667	1.54410	1.000	-4.9095	5.2428

*. The mean difference is significant at the 0.05 level.

Appendix 6

Values of the ANOVA test concerning the results of the meta-analysis for the Holdridge's life zones tropical dry, moist and wet forest

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Primary Forest	Between Groups	44356.235	2	22178.118	29.678	.000
	Within Groups	68004.141	91	747.298		
	Total	112360.376	93			
Secondary Forest	Between Groups	7827.898	2	3913.949	17.721	.000
	Within Groups	38209.502	173	220.864		
	Total	46037.401	175			
Disturbed Secondary Forest	Between Groups	521.339	2	260.669	.999	.376
	Within Groups	12007.153	46	261.025		
	Total	12528.492	48			
Riparian Forest	Between Groups	1066.713	2	533.357	8.567	.003
	Within Groups	996.132	16	62.258		
	Total	2062.845	18			
Early Secondary Growth	Between Groups	267.385	1	267.385	12.211	.001
	Within Groups	2386.748	109	21.897		
	Total	2654.133	110			
Pasture High Tree Cover	Between Groups	20529.450	2	10264.725	10.861	.000
	Within Groups	44418.749	47	945.080		
	Total	64948.199	49			
Pasture Low Tree Cover	Between Groups	215.946	2	107.973	34.124	.000
	Within Groups	104.415	33	3.164		
	Total	320.361	35			
Perennial Crops Conventional Multistrata Shade	Between Groups	1370.363	1	1370.363	34.248	.000
	Within Groups	1760.564	44	40.013		
	Total	3130.927	45			
Perennial Crops Organic Multistrata Shade	Between Groups	8609.705	1	8609.705	19.787	.000
	Within Groups	16534.334	38	435.114		
	Total	25144.039	39			
Perennial Crops Conventional with One Shade Stratum	Between Groups	9.900	1	9.900	.755	.387
	Within Groups	1744.776	133	13.119		
	Total	1754.675	134			

Values of the Bonferoni Post Hoc test concerning the comparison between the meta-analysis results of the three Holdridge's life zones tropical dry, moist and wet forest.

Dependent Variable	(I) LifeZones	(J) LifeZones	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Primary Forest	Tropical Wet Forest	Tropical Moist Forest	-60.11123*	1.65532E1	.001	-100.4852	-19.7372
		Tropical Dry Forest	32.27699*	1.15565E1	.019	4.0902	60.4638
	Tropical Moist Forest	Tropical Wet Forest	60.11123*	1.65532E1	.001	19.7372	100.4852
		Tropical Dry Forest	92.38822*	1.25882E1	.000	61.6850	123.0914
	Tropical Dry Forest	Tropical Wet Forest	-32.27699*	1.15565E1	.019	-60.4638	-4.0902
		Tropical Moist Forest	-92.38822*	1.25882E1	.000	-123.0914	-61.6850
Secondary Forest	Tropical Wet Forest	Tropical Moist Forest	13.18059*	2.35252	.000	7.4934	18.8678
		Tropical Dry Forest	29.75654*	1.06768E1	.018	3.9455	55.5676
	Tropical Moist Forest	Tropical Wet Forest	-13.18059*	2.35252	.000	-18.8678	-7.4934
		Tropical Dry Forest	16.57595	1.06021E1	.359	-9.0544	42.2063
	Tropical Dry Forest	Tropical Wet Forest	-29.75654*	1.06768E1	.018	-55.5676	-3.9455
		Tropical Moist Forest	-16.57595	1.06021E1	.359	-42.2063	9.0544
Disturbed Secondary Forest	Tropical Wet Forest	Tropical Moist Forest	-1.42967	6.67383	1.000	-18.0121	15.1527
		Tropical Dry Forest	-11.03253	8.98852	.678	-33.3662	11.3012
	Tropical Moist Forest	Tropical Wet Forest	1.42967	6.67383	1.000	-15.1527	18.0121
		Tropical Dry Forest	-9.60286	7.12425	.553	-27.3044	8.0987
	Tropical Dry Forest	Tropical Wet Forest	11.03253	8.98852	.678	-11.3012	33.3662
		Tropical Moist Forest	9.60286	7.12425	.553	-8.0987	27.3044
Pasture High Tree Cover	Tropical Wet Forest	Tropical Moist Forest	-49.06513*	1.05628E1	.000	-75.2892	-22.8410
		Tropical Dry Forest	-29.53022*	1.08690E1	.028	-56.5146	-2.5458
	Tropical Moist Forest	Tropical Wet Forest	49.06513*	1.05628E1	.000	22.8410	75.2892
		Tropical Dry Forest	19.53491	1.05628E1	.212	-6.6892	45.7590
	Tropical Dry Forest	Tropical Wet Forest	29.53022*	1.08690E1	.028	2.5458	56.5146
		Tropical Moist Forest	-19.53491	1.05628E1	.212	-45.7590	6.6892
Pasture Low Tree Cover	Tropical Wet Forest	Tropical Moist Forest	-4.93692*	.72619	.000	-6.7685	-3.1053
		Tropical Dry Forest	1.56792	.72619	.115	-.2637	3.3995
	Tropical Moist Forest	Tropical Wet Forest	4.93692*	.72619	.000	3.1053	6.7685
		Tropical Dry Forest	6.50484*	.83853	.000	4.3899	8.6198
	Tropical Dry Forest	Tropical Wet Forest	-1.56792	.72619	.115	-3.3995	.2637
		Tropical Moist Forest	-6.50484*	.83853	.000	-8.6198	-4.3899

Appendix 7

The Appendix 7 shows the values of the Mann-Whitney test concerning the comparison between the survey and meta-analysis data for the tropical wet forest.

Ranks

	Database Survey	N	Mean Rank	Sum of Ranks
PrimaryForest	1	6	8.33	50.00
	2	6	4.67	28.00
	Total	12		
Secondary Forest	1	46	25.76	1185.00
	2	4	22.50	90.00
	Total	50		
Disturbed Secondary Forest	1	7	4.57	32.00
	2	4	8.50	34.00
	Total	11		
Pasture with High tree Cover	1	17	11.24	191.00
	2	6	14.17	85.00
	Total	23		
Pasture with Low Tree Cover	1	17	9.00	153.00
	2	8	21.50	172.00
	Total	25		
Perennial Crop Conventional with Multistrata Shade	1	7	8.00	56.00
	2	4	2.50	10.00
	Total	11		

Test Statistics[b]

	Primary Forest	Secondary Forest	Disturbed Secondary Forest	Pasture with High Tree Cover	Pasture with Low Tree Cover	Perennial Crop Conventional with Multistrata Shade
Mann-Whitney U	7.000	80.000	4.000	38.000	.000	.000
Wilcoxon W	28.000	90.000	32.000	191.000	153.000	10.000
Z	-1.777	-.429	-1.907	-.910	-3.967	-2.652
Asymp. Sig. (2-tailed)	.076	.668	.056	.363	.000	.008
Exact Sig. [2*(1-tailed Sig.)]	.093[a]	.692[a]	.073[a]	.392[a]	.000[a]	.006[a]

a. Not corrected for ties.

b. Grouping Variable: Database Survey

Appendix 8

The Appendix 8 shows the values of the Mann-Whitney test concerning the comparison between the survey and meta-analysis data for the tropical moist forest.

Ranks

	Survey Database	N	Mean Rank	Sum of Ranks
Primary Forest	Database	5	3.80	19.00
	Survey	3	5.67	17.00
	Total	8		
Secondary Forest	Database	112	56.60	6339.00
	Survey	2	108.00	216.00
	Total	114		
Disturbed Secondary Forest	Database	36	18.56	668.00
	Survey	2	36.50	73.00
	Total	38		
Early Secondary Growth	Database	101	51.00	5151.00
	Survey	3	103.00	309.00
	Total	104		
Plantation	Database	1	1.00	1.00
	Survey	3	3.00	9.00
	Total	4		
Pasture with High Tree Cover	Database	18	11.11	200.00
	Survey	4	13.25	53.00
	Total	22		
Pasture with Low Tree Cover	Database	8	4.50	36.00
	Survey	4	10.50	42.00
	Total	12		
Pasture with No Tree	Database	1	1.00	1.00
	Survey	4	3.50	14.00
	Total	5		
Perennial Crop With Multistrata Shade	Database	22	11.50	253.00
	Survey	2	23.50	47.00
	Total	24		
Perennial Crop With One Shade Stratum	Database	106	53.50	5671.00
	Survey	2	107.50	215.00
	Total	108		
Annual Crop With One Shade Stratum	Database	1	1.00	1.00
	Survey	2	2.50	5.00
	Total	3		
Annual Crop With No Tree	Database	1	1.00	1.00
	Survey	2	2.50	5.00

Ranks

	Survey Database	N	Mean Rank	Sum of Ranks
Primary Forest	Database	5	3.80	19.00
	Survey	3	5.67	17.00
	Total	8		
Secondary Forest	Database	112	56.60	6339.00
	Survey	2	108.00	216.00
	Total	114		
Disturbed Secondary Forest	Database	36	18.56	668.00
	Survey	2	36.50	73.00
	Total	38		
Early Secondary Growth	Database	101	51.00	5151.00
	Survey	3	103.00	309.00
	Total	104		
Plantation	Database	1	1.00	1.00
	Survey	3	3.00	9.00
	Total	4		
Pasture with High Tree Cover	Database	18	11.11	200.00
	Survey	4	13.25	53.00
	Total	22		
Pasture with Low Tree Cover	Database	8	4.50	36.00
	Survey	4	10.50	42.00
	Total	12		
Pasture with No Tree	Database	1	1.00	1.00
	Survey	4	3.50	14.00
	Total	5		
Perennial Crop With Multistrata Shade	Database	22	11.50	253.00
	Survey	2	23.50	47.00
	Total	24		
Perennial Crop With One Shade Stratum	Database	106	53.50	5671.00
	Survey	2	107.50	215.00
	Total	108		
Annual Crop With One Shade Stratum	Database	1	1.00	1.00
	Survey	2	2.50	5.00
	Total	3		
	Database	1	1.00	1.00
	Survey	2	2.50	5.00
	Total	3		

Test Statistics[b]

	Primary Forest	Secondary Forest	Disturbed Secondary Forest	Early Secondary Growth	Plantation	Pasture with High Tree Cover
Mann-Whitney U	4.000	11.000	2.000	.000	.000	29.000
Wilcoxon W	19.000	6339.000	668.000	5151.000	1.000	200.000
Z	-1.056	-2.180	-2.225	-2.942	-1.414	-.596
Asymp. Sig. (2-tailed)	.291	.029	.026	.003	.157	.551
Exact Sig. [2*(1-tailed Sig.)]	.393[a]	.013[a]	.011[a]	.000[a]	.500[a]	.594[a]

a. Not corrected for ties.

b. Grouping Variable: Survey Database

Test Statistics[b]

	Pasture with Low Tree Cover	Pasture with No Tree	Perennial Crop With Multistrata Shade	Perennial Crop With One Shade Stratum	Annual Crop With One Shade Stratum	Annual Crop With No Tree
Mann-Whitney U	.000	.000	.000	.000	.000	.000
Wilcoxon W	36.000	1.000	253.000	5671.000	1.000	1.000
Z	-2.727	-1.491	-2.321	-2.416	-1.225	-1.225
Asymp. Sig. (2-tailed)	.006	.136	.020	.016	.221	.221
Exact Sig. [2*(1-tailed Sig.)]	.004[a]	.400[a]	.007[a]	.000[a]	.667[a]	.667[a]

a. Not corrected for ties.

b. Grouping Variable: Survey Database

Appendix 9

The Appendix 9 shows the values of the Mann-Whitney test concerning the comparison between the survey and meta-analysis data for the tropical dry forest.

Ranks

	Database	N	Mean Rank	Sum of Ranks
Primary Forest	1	84	44.19	3712.00
	2	5	58.60	293.00
	Total	89		
Secondary Forest	1	2	3.00	6.00
	2	5	4.40	22.00
	Total	7		
Disturbed Secondary Forest	1	6	3.50	21.00
	2	5	9.00	45.00
	Total	11		
Early Secondary Growth	1	10	7.70	77.00
	2	4	7.00	28.00
	Total	14		
Pasture With High Tree Cover	1	25	15.00	375.00
	2	8	23.25	186.00
	Total	33		
Pasture With Low Tree Cover	1	9	5.00	45.00
	2	8	13.50	108.00
	Total	17		
Perennial Crop Organic With Multistrata Shade	1	17	10.41	177.00
	2	3	11.00	33.00
	Total	20		
Perennial Crop Conventional With Multistrata Shade	1	39	20.79	811.00
	2	3	30.67	92.00
	Total	42		
Perennial Crop Organic With One Shade Stratum	1	17	11.29	192.00
	2	3	6.00	18.00
	Total	20		
Perennial Crop Conventional With One Shade Stratum	1	14	9.14	128.00
	2	3	8.33	25.00
	Total	17		
Perennial Crop Conventional With No Shade	1	1	2.00	2.00
	2	3	2.67	8.00
	Total	4		

Test Statistics[b]

	Primary Forest	Secondary Forest	Disturbed Secondary Forest	Early Secondary Growth	Pasture With High Tree Cover	Pasture With LowTree Cover
Mann-Whitney U	142.000	3.000	.000	18.000	50.000	.000
Wilcoxon W	3712.000	6.000	21.000	28.000	375.000	45.000
Z	-1.212	-.789	-2.764	-.283	-2.101	-3.481
Asymp. Sig. (2-tailed)	.226	.430	.006	.777	.036	.000
Exact Sig. [2*(1-tailed Sig.)]		.571[a]	.004[a]	.839[a]	.036[a]	.000[a]

a. Not corrected for ties.

b. Grouping Variable: Database

Test Statistics[b]

	Perennial Crop Organic With Multistrata Shade	Perennial Crop Conventional With Multistrata Shade	Perennial Crop Organic With One Shade Stratum	Perennial Crop Conventional With One Shade Stratum	Perennial Crop Conventional With No Shade
Mann-Whitney U	24.000	31.000	12.000	19.000	1.000
Wilcoxon W	177.000	811.000	18.000	25.000	2.000
Z	-.159	-1.343	-1.429	-.252	-.471
Asymp. Sig. (2-tailed)	.874	.179	.153	.801	.637
Exact Sig. [2*(1-tailed Sig.)]	.921[a]	.198[a]	.179[a]	.859[a]	1.000[a]

a. Not corrected for ties.

b. Grouping Variable: Database

Appendix 10

The Appendix 10 illustrates the number of experts' evaluation and meta-analysis data for the three Holdridge's life zone tropical dry forest, tropical moist forest and tropical wet forest.

First level	Second level	Third level	Tropical dry forest		Tropical moist forest		Tropical wet forest	
			Survey	Database	Survey	Database	Survey	Database
Forest	1. Tree cover, broadleaved evergreen, closed to open (>15%)	Undisturbed mature forest	4	-	4	-	6	-
		Mature forest	5	84	3	5	7	6
		Secondary forest	5	2	3	112	5	4
		Disturbed secondary forest	5	6	2	36	5	7
		Early secondary growth	4	10	3	101	7	-
		Plantation	5	-	3	1	7	-
	2. Tree Cover, broadleaved deciduous, closed (>40%)	Undisturbed mature forest	-	-	-	-	-	-
		Mature forest	-	-	-	-	-	-
		Secondary forest	-	-	-	-	-	-
		Disturbed secondary forest	-	-	-	-	-	-
		Early secondary growth	-	-	-	-	-	-
		Plantation	-	-	-	-	-	-
	3. Tree cover, broadleaved deciduous, open (15-40%)	Undisturbed mature forest	-	-	-	-	-	-
		Mature forest	-	-	-	-	-	-
		Secondary forest	-	-	-	-	-	-
		Disturbed secondary forest	-	-	-	-	-	-
		Early secondary growth	-	-	-	-	-	-
		Plantation	-	-	-	-	-	-
	4. Tree cover, needle-leaved evergreen, closed to open (>15%)	Undisturbed mature forest	-	-	-	-	-	-
		Mature forest	-	-	-	-	-	-
		Secondary forest	-	-	-	-	-	-
		Disturbed secondary forest	-	-	-	-	-	-
		Early secondary growth	-	-	-	-	-	-
		Plantation	-	-	-	-	-	-
	5. Tree cover, needle-leaved deciduous, closed to open (>15%)	Undisturbed mature forest	-	-	-	-	-	-
		Mature forest	-	-	-	-	-	-
		Secondary forest	-	-	-	-	-	-
		Disturbed secondary forest	-	-	-	-	-	-
		Early secondary growth	-	-	-	-	-	-
		Plantation	-	-	-	-	-	-
	6. Tree cover, mixed leaf type, closed to open (>15%)	Undisturbed mature forest						
		Mature forest	-	-	-	-	-	-
		Secondary forest	-	-	-	-	-	-
		Disturbed secondary forest	-	-	-	-	-	-
		Early secondary growth	-	-	-	-	-	-
		Plantation	-	-	-	-	-	-

First level	Second level	Third level	Tropical dry forest Survey	Tropical dry forest Database	Tropical moist forest Survey	Tropical moist forest Database	Tropical wet forest Survey	Tropical wet forest Database
	7. Mosaic of tree cover and other natural vegetation		-	16	-	-	-	-
	8. Tree Cover, burnt (mainly boreal forests)		-	-	-	-	-	-
Wet land	9. Tree cover, closed to open (>15%), regularly flooded, saline water: Mangrove Forests		4	-	1	-	4	-
	10. Tree cover, closed to open (>15%), regularly flooded, fresh or brackish water: Swamp Forests		3	-	1	-	4	-
	11. Regularly flooded (>2 month) Shrub or Herbaceous cover		4	-	1	-	4	-
Shrub land	12. Closed to open (>15%), evergreen (broadleaved or needle-leaved)	Shrub land, no tree cover	3	-	2	-	6	-
		Shrub land, with tree cover	3	-	2	-	6	-
	13. Closed to open (>15%), deciduous (broadleaved)	Shrub land, no tree cover	-	-	-	-	-	-
		Shrub land, with tree cover	-	-	-	-	-	-
	14. Sparse Herbaceous or sparse Shrub cover		3	-	2	-	6	-
Grass land	15. Herbaceous cover, closed to open (>15%)	Grassland, without tree cover, unused	4	-	2	-	6	-
		Grassland, with tree cover, unused	4	-	2	-	7	-
		Grassland, no tree cover, low impact use	4	-	2	1	4	-
		Grassland, no tree cover, intense use	4		2		4	
		Grassland, low tree cover, low impact use	4	9	2	8	5	1
		Grassland, low tree cover, intense use	4		2		5	
		Grassland, high tree cover, low impact use	4	16	2	18	4	1
		Grassland, high tree cover, intense use	4		2		4	
		Grassland, sparse herbaceous cover, intense use	4	-	2	-	5	-
Agriculture	16. Cropland (upland crops or inundated/ flooded crops as e.g. rice)	Annual crop, conventional	3	-	2	1	4	-
		Annual crop, organic	3	-	2	-	4	-
		Annual crop, flooded (e.g. rice)	3	-	2	-	4	-

First level	Second level	Third level	Tropical dry forest		Tropical moist forest		Tropical wet forest	
			Survey	Database	Survey	Database	Survey	Database
	17. Mosaic of Cropland/Tree cover/ Other Natural Vegetation	Perennial crop, conventional	3	10	2	-	4	-
		Perennial crop, organic	3	-	2	-	4	-
		Annual crop, conventional, shade tree cover	3	1	2	1	4	-
		Annual crop, organic, shade cover	3	-	2	-	4	-
		Perennial crop, conventional, shade tree cover	3	14	2	121	4	-
		Perennial crop, organic, shade tree cover	3	17	2	-	4	-
		Annual crop, conventional, multi strata tree cover	3	-	2	-	4	-
		Annual crop, organic, multi strata tree cover	3	-	2	-	4	-
		Perennial crop, conventional, multi strata tree cover	3	39	2	7	4	-
		Perennial crop, organic, multi strata tree cover	3	17	2	-	4	7
	18. Mosaic of Cropland / Shrub or Herbaceous cover		-	-	-	-	-	-
Artificial Areas	19. Urban area(s)							
		Unpaved road	4	-	2	-	3	-
		Rail	4	-	2	-	3	-
		Urban, high intensity	4	-	2	-	3	-
		Urban, medium intensity	4	-	2	-	3	-
		Urban, low intensity	4	-	2	-	3	-
		Urban green	4	-	2	-	3	-
		Industrial, high intensity	4	-	2	-	3	-
		Industrial, medium intensity	4	-	2	-	3	-
		Industrial, low intensity	4	-	2	-	3	-
		Extraction sites	4	-	2	-	3	-
		Waste sites	3	-	2	-	3	-
Bare Area	20. Bare Areas		-	-	-	-	-	-
Snow and Ice	21. Snow and Ice		-	-	-	-	-	-
Water Bodies	22. Water Bodies		-	-	-	-	-	-