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Report on data available on tree cover in pastures along the MBC and its impact on productivity and biodiversity

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1. Introduction

Across Mesoamerica[1], large areas of tropical forest have been converted to pastures for cattle production. Pastures account for 2.2 to 48.5% percent of the total land use within each country, and constitute the main agricultural land use in 6 of the 9 countries (**Table 1**). Almost all ecological regions within Mesoamerica have been strongly affected by the conversion of forests to pastures: historically most cattle production occurred in the dry Pacific lowlands, but cattle production has expanded into the mountainous regions and across to the wet Atlantic lowlands in the last decades, so that virtually no region of the Mesoamerican isthmus remains unaffected. In fact, in many regions, pastures are the dominant land use and constitute the agricultural matrix.

Although highly deforested and fragmented, many of the pasture-dominated landscapes still retain some on-farm tree cover, in the form of small (and often isolated) forest fragments, strips of riparian forest, dispersed trees in pastures and/or live fences. This on-farm tree cover is important for both farm productivity (providing shade and forage for cattle, while providing timber and firewood to farmers), and for biodiversity conservation, through serving as habitats and resources for plant and animal species (Harvey et al. 2006).

2. Tree cover within pasture-dominated landscapes

Despite its importance, surprisingly little is known about the patterns of tree cover within pastoral landscapes in Mesoamerica and to date, there is no readily-accessible information on the patterns of tree cover diversity, density, type and arrangement within the Mesoamerican region. This information is important not only for understanding what tree resources currently exist within these landscapes, but also for evaluating both the potential conservation and productive benefits of retaining trees within pasture landscapes and for informing land use and agricultural policies that seek to enhance the sustainable management of pasture-dominated landscapes. Detailed information on the types, density and spatial arrangement of tree cover within pasture-dominated landscapes is also necessary for landscape and regional-scale conservation efforts that hope to take advantage of the tree cover within agricultural areas to provide supplementary habitat and resources to wildlife and to enhance landscape connectivity. This information is particularly relevant to the Mesoamerican Biological Corridor which seeks to establish a series of national and transnational biological corridors to link existing protected areas (Miller et al. 2000). As many of the proposed biological corridors include areas currently under pasture production (**Table 2**), understanding the patterns of on-farm tree cover within these landscapes will be critical for designing appropriate conservation and management strategies that facilitate biodiversity conservation within productive cattle systems.

[1] For the purposes of this report, Mesoamerica is taken to include: Mexico, El Salvador, Belize, Honduras, Guatemala, Nicaragua, Costa Rica, Panama and Colombia.

Table 1. *Prominence of pastoral landscapes across Mesoamerica, Mexico and Colombia.*

COUNTRY	Land area (1000 ha)	Arable land (1000 ha)	Perm-anent crops (1000 ha)	Pastures (1000 ha)	Forest and wood-land (1000 ha)	Other land types (1000 ha)	Annual deforest-ation rate (%)	Arable land (%)	Permanent crops (%)	Pastures (%)	Forest and woodland (%)	Other land types (%)
Belize	2280	64	35	50	1348	783	-2.3	2.8	1.5	2.2	59.1	34.3
Colombia*	103870	2818	1727	40920	49601	8804	-0.4	2.7	1.7	39.4	47.8	8.5
Costa Rica	5106	225	300	2340	1968	273	-0.8	4.4	5.9	45.8	38.5	5.3
El Salvador	2072	640	250	794	121	267	-4.6	30.9	12.1	38.3	5.8	12.9
Guatemala	10843	1360	545	2602	2850	3486	-1.7	12.5	5.0	24.0	26.3	32.1
Honduras	11189	1068	359	1508	5383	2871	-1.0	9.5	3.2	13.5	48.1	25.7
Mexico*	190869	24800	2500	80000	55205	28364	-1.1	13.0	1.3	41.9	28.9	14.9
Nicaragua	12140	1917	234	4815	3278	1896	-3	15.8	1.9	39.7	27.0	15.6
Panama	7443	540	148	1500	2876	2379	-1.6	7.3	2.0	20.2	38.6	32.0

Source: FAOSTAT 2002; FRA 2000; FAO 2001.
*Data refer to the entire country (not just the area included within Mesoamerica)
Percentages refer to the total land area.

***Table 2**. Importance of pastures as a land use within selected national biological corridors within the larger Mesoamerican Biological Corridor.*

Biological corridor	Country	Total areas of biological corridor (ha)	Forest cover** (%)	Pastures (%)	Other land uses (%)	Source
Turrialba - Jimenez	Costa Rica	71,386	40	21	39	Florian Rivero, EM. 2005. Tropical bird assemblages in coffee agroforestry systems: exploring the relationships between the landscape context, estructural complexity and bird communities in the Turrialba - Jimenez Biological Corridor, Costa Rica.
PN Tortuguero – RN Vida Silvestre Barra del Colorado.	Costa Rica-Panama	85,741	78	NA	22	Corredor Biológico Mesoamericano. 2005. Corredores biólogicos de Costa Rica.Proyecto CBM. 209 p.
El Castillo-San Juan	Nicaragua	38,241	83	8	9	Corredor Biológico Mesoamericano. 2006. Ficha técnica binacional corredor El Castillo-San Juan- La Selva. CMB 1ª. Ed. Managua, Proyecto CBM. 64 p.
Guanaca altitudinal	Panamá	89,507	14	30	56	ANCON (Asociación Nacional para la Conservación de la Naturaleza) 1998. Planificación metodológica y apoyo a la promoción de corredores biológicos locales (propuestos) en la República de Panamá. 76 p
Means		**70,502**	**55**	**28**	**23**	
Max		**667,875**	**100**	**58**	**56**	
Min		**1,190**	**14**	**6**	**0**	

2.1 Scope of the review of tree cover

The overall aim of this part of the review is to provide a synthesis of knowledge on the patterns of tree cover within pasture-dominated landscapes in Mesoamerica. Specific objectives include: 1) to identify the data available on the patterns of tree cover within pasture-dominated landscapes of Mesoamerica and 2) to synthesize the key findings related to patterns of tree diversity, density and spatial arrangement

2.2 Review method

In order to identify publications related to tree cover in pasture-dominated landscapes, we used ISI (Institute of Scientific Information) Web of Science Database and the Revista de Agroforesteria en las Americas to search for post 1990 peer-reviewed manuscripts containing original data. Books, reviews, theses, white papers and work conducted outside of the Mesoamerican Biological Corridor were excluded. The search of these ISE database was conducted during the week of October 2nd through October 6th of 2006.

We used the following two topic searches in ISI Web of Science to build our initial list of publications:

1) Topic Search for ((“riparian forest” ***or*** “forest” *or* “fragment” ***or*** “silvopastoral” ***or*** “live fence*” *or* “isolated tree*”***or*** “remnant tree*” ***or*** “fodder bank” ***or*** dispersed tree* ***or*** “tree cover” ***or*** “landscape change” ***or*** connectivity ***or*** Corridor* ***or*** “tree regeneration” ***or*** “bat*” ***or*** “bird*” ***or*** “amphibian*” ***or “***beetle*” ***or*** “spider” ***or*** “mammal*” ***or*** “reptile*” ***or*** “biodiversity” ***or*** “tree*” ***or*** “epiphyte*” ***and*** (“pasture” ***or*** “cattle”) ***and*** (“Mexico” ***or*** “Belize” ***or*** “Honduras” ***or*** “Guatemala” ***or*** “Nicaragua” ***or*** “El Salvador” ***or*** “Costa Rica” ***or*** “Panama” ***or*** “Colombia”))

2) Topic Search for ((“Fragmented” ***or*** “countryside biogeography” ***or*** “agricultural landscape”) ***and*** (“bird*” ***or*** “bat*” ***or*** “amphibian*” or “beetle*” ***or*** “spider*” ***or*** “insect*” ***or*** “mammals*” ***or*** “plant*” ***or*** “tree*” ***or*** “epiphyte*” ***or*** “reptile*” ***or*** “biodiversity”) ***and*** (“Mexico” ***or*** “Belize” ***or*** “Honduras” ***or*** “Guatemala” ***or*** “Nicaragua” ***or*** “El Salvador” ***or*** “Costa Rica” ***or*** “Panama” ***or*** “Colombia”))

The first search yielded 433 articles, and the second 193. Forty of these articles were duplicates for a net of 586 articles identified in the search. We read the complete abstracts for these 586 articles and eliminated manuscripts referring to studies outside the MesoAmerican Biological Corridor, particularly Amazonian Colombia, and Central to Northern Mexico. We also excluded articles that did not contain original data such as published reviews, or theoretical studies and models. Articles that did not clearly identify pastures as treatments or as critical elements of the study were also excluded.

2.3 Database

We created a database in Microsoft Access 2000, where data from all reviewed manuscripts were entered. Data were organized into three principal categories: 1) Data referring to the manuscript's general themes and topic (Appendix 1, part a, b), 2) Data referring to tree cover in pastures and pastoral landscapes (Appendix 1 part c), and 3) Data referring to animal biodiversity in pastures and pasture landscapes (Appendix 1, part d). The database can be accessed through the Corridor website at http://corridor.bangor.ac.uk/.

Database main page

The first page of the database contains the citation information for each manuscript, including the abstract and summary data for the manuscript. We include detailed information on the study area, including geographic coordinates, the type of study (experimental or descriptive), the scale of the study from plot to region, and reference as to the general content of the article i.e whether the study focuses on animal biodiversity, tree diversity, productivity or whether the study is a landscape characterization. We included categorical fields indicating which ecosystem functions, land use types, production systems, pasture types (active or abandoned), type of grass, and they type of tree data the manuscript contains. These fields simply indicate presence/absence of such data. A screenshot of the entry page of the database is found in Appendix 1 Figure 1 and includes the value lists for all the categorical fields mentioned here.

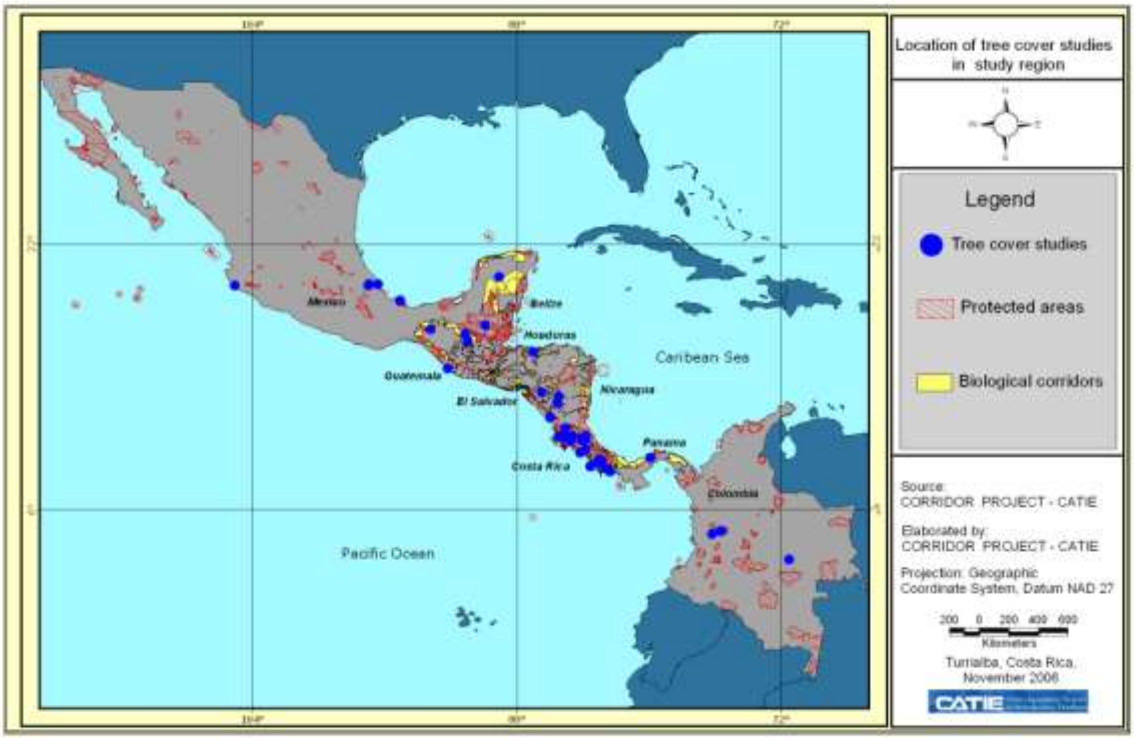
Tree cover

The tree cover page of the database collects information on tree cover mentioned in each manuscript. Data on tree cover was categorized by land use types including: pastures with trees, pastures without trees, pastures where tree cover was not mentioned, riparian forests, live fences, improved fallows, intensive silvopastoral systems, charrals, tree plantations, primary forest, secondary forest, orchards, annual crops, and perennial crops. The tree cover page summarizes data on the total and mean tree species richness and abundance per land use. In addition the data on the density of trees per hectare, the mean diameter breast height (DBH), tree height, basal area per ha., Shannon index of diversity, index of evenness, tree canopy cover per plot, pasture or landscape, and the percent copy cover were all recorded when available. We included categorical fields which asked whether the study contained species lists, data on the spatial distribution of trees, the frequency of individual species, information on regeneration, use of trees by wildlife, utilitarian use of trees, and on percent tree cover. We also considered whether the trees discussed in the manuscript were remnant, planted, or from natural regeneration. A second categorical field collects information on the methods used to collect the data. And a final fields records the minimum dbh (numerical) used in measuring trees, the growth form studied (categorical), the grass species included (text), and the pasture type (categorical). A screenshot of the tree cover page of the database is found in Appendix 1 Figure 2.

2.4 Information available on tree cover within pasture-dominated landscapes

Where have the studies been conducted?

A total of 96 scientific papers contain information on the vegetation within pastoral landscapes in the Mesoamerican region (**Map 1**), with 82 of these papers including data on trees and the remainder including information on other plant forms (e.g., epiphytes, shrubs, herbs, seeds, vine). Most of these papers stem from Costa Rica (46), Mexico (26) or Nicaragua (12). In contrast, there is little information on on-farm tree cover in the remaining countries, with six or fewer published papers describing patterns of tree cover in Colombia, Guatemala, Honduras and Panama, and no published studies being available for either Belize or El Salvador (**Figure 1**).



Map 1. *Pastoral landscapes in Mesoamerica where studies of tree cover have been conducted, relative to protected areas, and biological corridors.*

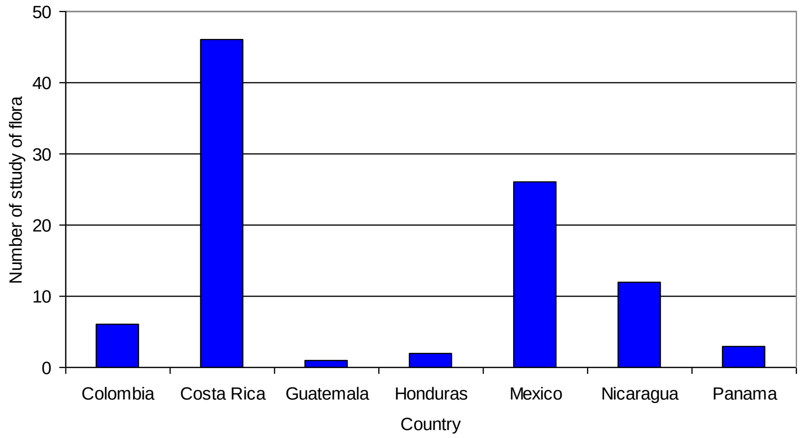


Figure 1. *Numbers of studies of flora (including trees, epiphytes, shrubs and herbaceous plants) in pasture dominated landscapes in different countries within the Mesoamerican region and Colombia.*

The majority of the studies are focused on a handful of landscapes that have been studied in detail by specific projects or research groups (**Table 3, Appendix 2**). For example, almost all of the studies on tree diversity in Costa Rica stem from three landscapes: Cañas (6 studies) and Río Frío (5 studies), which were the sites of the FRAGMENT[2] project led by CATIE and the Bangor University and Las Cruces Biological Station (6 studies) which has been the site for the Countryside Biogeography projects led by Stanford University. Similarly, almost all of the studies from Mexico are from the Los Tuxtlas region of Veracruz or Chiapas, where the Estacion Biologica Los Tuxtlas[3] and EcoSur are respectively based. In Nicaragua, most studies stem from either Rivas or Matiguás, where both the FRAGMENT and GEF-SSP[4] projects have been working, whereas in Colombia, most work has been conducted at the GEF-SSP project site in Quindio. Key regional organizations leading the work on tree cover within pasture-dominated landscapes include CATIE (a regional institution), CIPAV (Colombia), Nitlapan

[2] FRAGMENT= 'Developing methods for assessing the impact of tree cover on farm productivity and regional biodiversity', an EU-project led by CATIE, UWB, Nitlapan, University of Gottingen, UNA, and Fundacion Cocibolca
[3] Much of the work here has been led by Alejandro Estrada, Sergio Guevara and Javier Laborde.
[4] 'ADD name here', a project involving CATIE, World Bank, Nitlapan, CIPAV, UNA and American Bird Conservancy.

(Nicaragua), CORPOICA (Colombia), Fundación Cocibolca (Nicaragua), UNA (Costa Rica), Instituto Alexander von Humboldt (Colombia), UNAM (Mexico) and ECOSUR (Mexico). Organizations from outside the region that have also been involved in this research include Stanford University, the Bangor University, the American Bird Conservancy and the University of Gottingen, among others.

***Table 3**. Summary of the number of papers describing tree cover in pastoral landscapes within the Mesoamerican region.*

Country	Total number of studies describing tree cover in pastures	Key landscapes studied	Key research institutions	Key scientific groups or projects that have already published information	Key scientific groups or projects that are generating additional information (which is not yet published)
Colombia	6	Zona Andina, Quindío, Valle de Cauca	CIPAV, CORPOICA, Instituto Alexander von Humbolt	GEF-SPP project, Proyecto Andes	GEF SPP project, Proyecto Andes
Costa Rica	46	Cañas, Rio Frio, La Selva-San Juan biological corridor, Las Cruces	CATIE, Stanford University, UNA	FRAGMENT, GEF-SSP, IGERT, Research group led by Gretchen Daily	FRAGMENT, GEF SSP projects
Guatemala	1	Petén	CATIE		NORAD project
Honduras	2	Juncal, Copán	CATIE		NORAD project, BNPP
Mexico	26	Chiapas, Los Tuxtlas-Veracruz	ECOSUR, UNAM, Instituto de Ecología	Research group led by Alejandro Estrada; Research group led by Sergio Guevara and Javier Laborde	
Nicaragua	12	Muy Muy, Rivas, Matiguás	Nitlapán, Fundacion Cocibolca, CATIE	FRAGMENT, GEF-SSP, NINA[5]	FRAGMENT, GEF SSP, NINA, NORAD project, BNPP
Panama	3		CATIE	Research group led by Lisa Petit and Daniel Petit.	
Total	**96**				

In addition to the published information, there is a lot of information on silvopastoral systems and on-farm tree cover that has not been published (and is available in student theses or project reports). For example, there have been numerous projects in the Petén of Guatemala (including several led by CATIE) which have characterized and promoted silvopastoral systems, but no published articles are available. In addition, several key projects are underway which will likely generate additional information on tree cover within pasture-dominated landscapes in the next few years. For example, additional information on tree cover is likely to be available in Nicaragua, Honduras and Guatemala in the next five years, as a result of the ongoing NORAD degraded pastures project[6] and the BNPP[7] project, among others. Similarly, ongoing research in the La Selva-San Juan biological corridor in Costa Rica, as a result of the ongoing IGERT NSF project[8], led by CATIE and the University of Idaho, will also likely result in additional publications in the near future. Additional publications on tree cover in pastoral landscapes are also expected from the FRAGMENT and GEF-SSP projects, for Costa Rica, Nicaragua and Colombia. A list of known, ongoing projects that are currently collecting or analyzing information on on-farm tree cover in pastoral landscapes is included in **Table 3**.

Types of landscapes studied

In most cases, the landscapes that have been studied were selected as study sites because they were either in critical cattle production areas or were landscapes that were typical of production systems in the region. For example, the Cañas, Esparza and Rivas landscapes are typical of cattle production landscapes present throughout the Tropical Dry Forests of the Pacific region of Mesoamerica, while the Matiguás landscape in Nicaragua represents the cattle production landscapes typical of tropical humid forest regions.

However in a few cases the study landscapes were selected due to their presence near a large biological reserve (e.g, the Los Tuxtlas site in Veracruz, Mexico and the Las Cruces site in Costa Rica). Only one of the studied

[5] 'Improving Forage Value of Degraded Pastures in Central America: Local Knowledge, Grazing Responses, and Species and Landscape Diversity', a project between CATIE, NINA and NORAD.
[6] Led by CATIE
[7] 'Impact of Improved Cattle Production Practices on Biodiversity in Central America. Bank of Netherlands Partnership Programme, led jointly by CATIE and the World Bank
[8] 'Biodiversity Conservation and Sustainable Production in Tropical and Temperate Fragmented Landscapes', joint grant between the University of Idaho and CATIE, funded by the National Science Foundation.

landscapes (in the Yucatan of Mexico) is situated within a biological corridor (Cardel-Jalapa Biological Corridor; Bojorges and López-Mata 2005), however many of the landscapes are located near proposed biological corridors or occur in landscapes typical of areas within the proposed biological corridors (**Map 1**). The total number of articles reporting research within a biological corridor were 20 (**Table 4**).

Table 4. *Summary of the number of papers describing tree cover in pastoral landscapes within biological corridors*

AREA	Biological corridors	HOLDRIGE_L	COUNTRY	REFERENCE
Cañas	Miravalles-Tenorio	Tropical Dry Forests	Costa Rica	Cárdenas et al. 2003.
Cañas	Miravalles-Tenorio	Tropical Dry Forests	Costa Rica	Esquivel et al. 2003
Cañas	Miravalles-Tenorio	Tropical Dry Forests	Costa Rica	Ghazoul and McLeish 2001.
Cañas	Miravalles-Tenorio	Tropical Dry Forests	Costa Rica	Harvey et al. 2005
Cañas	Miravalles-Tenorio	Tropical Dry Forests	Costa Rica	Muñoz et al. 2003
Cañas	Miravalles-Tenorio	Tropical Dry Forests	Costa Rica	Villanueva et al. 2003
Esparza	Montes del aguacate	Tropical Dry Forests	Costa Rica	Camargo et al. 2000.
Las Cruces, Coto Brus	Boruca-Changuena-Rio Canasta	Subtropical wet forest	Costa Rica	Carpenter et al. 2004a.
Las Cruces, Coto Brus	Boruca-Changuena-Rio Canasta	Subtropical wet forest	Costa Rica	Carpenter et al. 2004b.
Las Cruces, Coto Brus	Boruca-Changuena-Rio Canasta	Subtropical wet forest	Costa Rica	Jones et al. 2003
Las Cruces, Coto Brus	Boruca-Changuena-Rio Canasta	Subtropical wet forest	Costa Rica	Luck and Daily 2003.
Las Cruces, Coto Brus	Boruca-Changuena-Rio Canasta	Subtropical wet forest	Costa Rica	Mayfield and Daily 2005.
Las Cruces, Coto Brus	Boruca-Changuena-Rio Canasta	Subtropical wet forest	Costa Rica	Mayfield et al. 2006.
Las Cruces, Coto Brus	Boruca-Changuena-Rio Canasta	Subtropical wet forest	Costa Rica	Peterson and Haines 2000.
Las Cruces, Coto Brus	Boruca-Changuena-Rio Canasta	Subtropical wet forest	Costa Rica	Schlaepfer and Gavin 2001.
Pacific Coastal Plain of Chiapas.	La sepultura	Tropical Dry Forests	Mexico	Otero-Arnaiz et al. 1999.
Montes Azules Biosphere Reserve (MABR), Chiapas.	Bonampak-Yaxchilán-La Cojolita	Tropical Dry Forests	Mexico	Benitez-Malvido 2006.
Ocosingo Valley, Chiapas.	Chichinautzin	Tropical wet forest	Mexico	Greenberg et al. 1997.
La Pavas, Canal de Panama.	Transístmico	Premontane wet forest	Panama	Hooper et al. 2004.
La Pavas, Canal de Panama.	Transístmico	Premontane wet forest	Panama	Hooper et al. 2005.

The majority of the study sites are typical cattle production landscapes, dominated by pastures (with pastures usually accounting for >40 % of the total area) but with small patches of other land use (forest fragments, isolated trees, live fences, fallows and crop areas interspersed within the pasture matrix (**Table 5**). Most of these landscapes are dominated by naturalized grass species, although increasingly farmers within the landscapes are increasing the area of pasture under improved, exotic grasses such as *Brachiaria* species.

The landscapes studied represent the full range of Holdridge life zones present in the region, from tropical dry forests to tropical wet forests (**Table 6, Appendix 2**). However, most of the studies appear to have been conducted in the lowlands, and many fewer in mountainous regions, likely reflecting the greater dominance of pastures in lowlands.

What types of tree cover have been characterized?
The studies of tree cover within pastoral landscapes have focused on the wide range of tree cover types that occur in these landscapes **(Figure 2, Appendix 3**). These tree cover types range from forested ecosystems (primary forest, secondary forest, riparian forests), to planted tree cover (e.g. perennial crops and forest plantations, live fences) to trees occurring dispersed within pastures. However, the greatest number of studies has been conducted in pastures with dispersed trees (60), secondary forests (46), live fences (32) and primary forests (27). Most studies have characterized tree cover in several types of tree cover, with a mean of 3.3 land uses per study (range: 1-9).

Table 5. *Characterization of the land use within key pasture-dominated landscapes in which tree cover has been characterized.*

Landscape	Country	Holdridge life zone	Total area of landscape (ha)	% pasture	% forest	% riparian forest	% charral	% live fences and plant-ations	% annual crops	% perennial crops	% other (roads, houses, clouds, etc.)	Source
Aranzu, Caldas	Colombia	Montane pluvial forest	2,574.89	59.61	20.25	0.5	2.76	2.98	2.21	2.11	9.58	Otero, et al 2006
Cuenca hidrográfica del río La Vieja, Valle, Quindío.	Colombia	Montane pluvial forest	3684.5	60.23	7.03	12.61	1.29	0.16	4.23	9.75	4.71	Proyecto SPS-GEF
Filandia, Quindio and Pereira, Risaralda	Colombia	Montane pluvial forest	2,500.00	45.4	41.4	NA	NA	6	NA	NA	7.2	(GEF-Humboldt)[1]
Cañas	Costa Rica	Tropical Dry Forest	13,051.00	48.4	15.27	7.92	2.83	0.35	22.91	0.05	2.27	Harvey et al., in press
Esparza	Costa Rica	Subtropica l Wet forest	4,471.17	65.22	9.57	17.17	1.87	1.61	0.57	0.53	3.46	Proyecto SPS-GEF
Las Cruces	Costa Rica	Subtropica l Wet forest	227.00	30	25	NA	NA	NA	NA	25	20	Daily et al 2003
Río Frío	Costa Rica	Tropical Wet Forest	15,987.00	47.05	15.85	6.03	2.97	2.85	0.03	20.63	4.59	Harvey et al., in press
Los Tuxclas	Mexico	Tropical Wet Forest	155,122.00	58.75	34.37	NA	NA	1.09	NA	3.85	1.94	Los Tuxtlas. 2006[2]
Matiguás	Nicaragua	Tropical Humid Forest	10,108.00	68.23	6.88	1.39	6.8	8.67	0.66	0.5	6.87	Harvey et al., in press
Rivas	Nicaragua	Tropical Dry Forest	11,621.00	56.72	15.62	5.92	13.92	0	5.06	0.33	2.43	Harvey et al., in press

[1]Proyecto Conservación y uso sostenible de la biodiversidad de los Andes colombianos
[2]Programa de conservación y manejo Reserva de la biosfera

Table 6. *Number of plant biodiversity studies in pastoral landscapes for ecosystem types by country.*

Holdrige Life zone	Country							Total
	Colombia	**Costa Rica**	**Guatemala**	**Honduras**	**Mexico**	**Nicaragua**	**Panama**	
Lower Montane wet forest	1	13			1			15
Montane pluvial forest	1	1						2
Premontane wet forest	2	2					2	6
Subtropical wet forest		7	1	2	2	3		15
Tropical dry forest	1	9			4	7		21
Tropical wet forest	1	14			19	2	1	37
Total	**6**	**46**	**1**	**2**	**26**	**12**	**3**	**96**

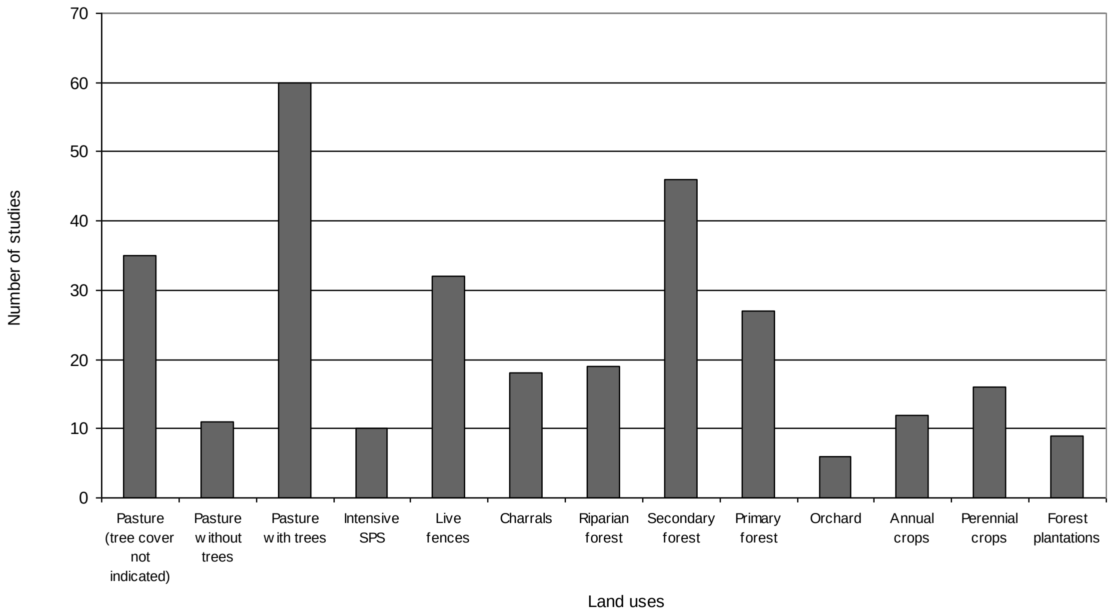


Figure 2*. Summary of the number of studies of tree diversity in different land uses occurring in pastoral landscapes of Mesoamerica and Colombia.*

What types of data have been collected?

Most studies have characterized tree cover in terms of abundance (and/or density) and species richness (**Figure 3**); a summary of the type of information present in all 96 studies of tree cover, is found in **Appendix 4** and **5**). Data on the structural characteristics of tree cover (such as height and diameters) are present in about a quarter of the studies, while data on basal area is scarce. Only a few studies have calculated indices of tree diversity (e.g. Shannon diversity indexs) and generated species-area curves. There are also no studies that have explicitly looked at the phenology of trees within pastoral landscapes. There is also very little information available on the canopy cover (measured as the percent of the pasture area covered by tree crowns) within pastures, with the exception of studies by Cajas-Giron and Sinclair (2001), Berninger and Salas 2003, Esquivel et al. (2003), Mayfield and Daily (2005), Mayfield et al. (2006), Williams-Linera et al. (1998) and Villacis et al. (2003). Similarly, few studies have looked explicitly at the spatial arrangement of tree cover either within a given land use or across the landscape. The only studies that provide spatially explicit information on tree cover are Chacon and Harvey (2006) which examines the spatial distribution of live fences and Guevara et al. (1998) which explores the distances between dispersed trees and forest fragments. Interesting data on the spatial arrangement of trees within pastures has been collected by Esquivel et al., but has not yet been published. There is even less information on the spatial arrangement of crown cover, forest cover or on-farm tree cover across entire landscapes, and few studies that consider their role in contributing to landscape connectivity (but see Chacon and Harvey 2006 and Guevara et al. 1998).

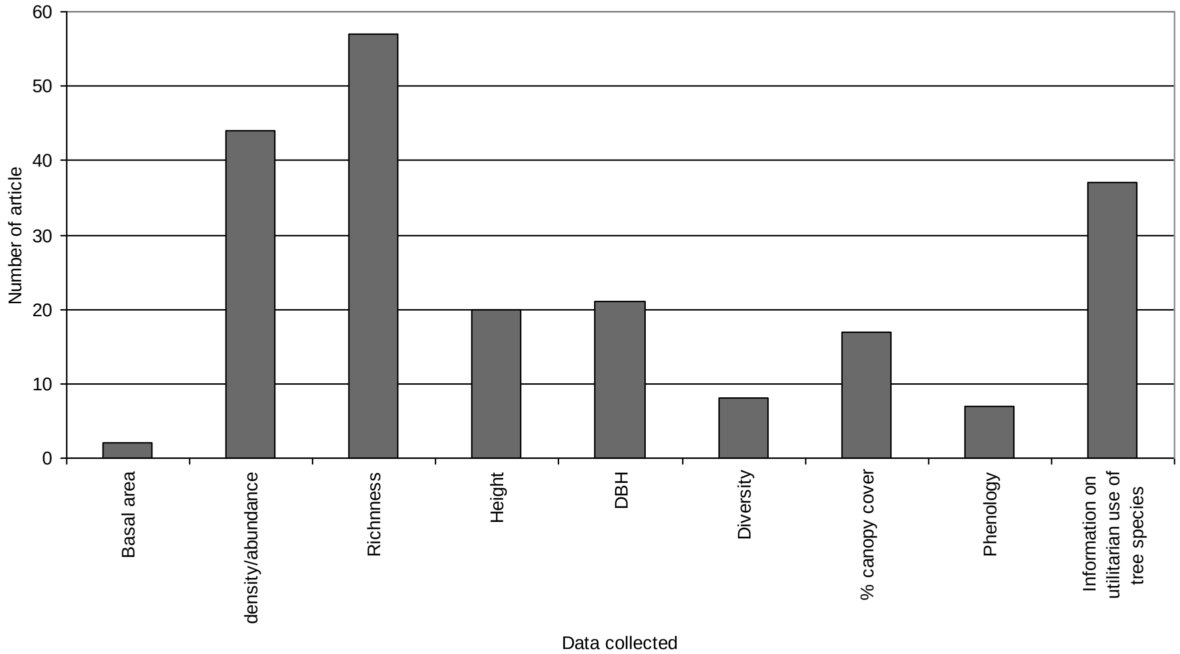


Figure 3. *Types of data collected in the studies of tree diversity in pastoral landscapes of Central America (n=82 studies).*

Part of the reason for the lack of spatial information is the scale at which these studies have been conducted. The majority of studies have been conducted at the plot scale (51 of the 96 studies), while only 18 have documented tree cover across the entire landscape.

Many of the studies provide information on the uses of trees found within the pastoral landscape, classifying species in terms of their value as timber, firewood, fruits, fodder and other products. Of the 82 studies that looked specifically at trees, 37 included information on potential uses of the tree species present in the study area. However, little information is available on the degree to which these tree species are actually used by farmers.

Temporal and spatial characteristics of vegetation studies in pasture-dominated landscapes
Almost all of the available information on the vegetation within pasture-domianted landscapes comes from one-time characterizations. Of the 96 vegetation studies, 35 studies consisted of a single characterization at a given point in time. Only 47 studies monitored tree cover over time and even these studies only covered very short time periods (maximum length of 3 years). Therefore, very little is known about how tree cover within pastures or across land uses within the pasture-dominated matrix have changed in the past or how the patterns of tree cover may change in the future.

The only information of the dynamics of tree cover within pastoral landscapes comes from studies of natural regeneration within pastures. A total of 41 studies characterized tree regeneration within pastures, though of these studies (**Appendix 6**), most looked at regeneration within fenced off or abandoned areas giving a perhaps unrealistic view of the potential regenerative capacity under normal management conditions. Only a handful of studies examined regeneration within active pastures (e.g., Esquivel and Calle 2002, Camargo 2000, Carpenter et al. 2004a, 2004b, Carpenter et al. 2004, Harvey, 2000a, Harvey 2000b, Mayfield et al. 2006, Mayfield et al. 2006, Stern et al. 2002). Of the 41 studies examining tree regeneration, 22 provided information on saplings and 24 on seedlings. Information on seed rain (13 studies) and seed banks (8 studies) was less common.

2.5 Tree abundance, diversity and spatial arrangement

Dispersed trees in pastures
Of the 82 studies that provide information on tree diversity within pasture-dominated landscapes, a total of 39 studies provide detailed, original data on the diversity of isolated trees in pastures. Mean tree densities in pastures (n= 15 studies) range from 1.2 trees per hectare to 100 trees per hectare, with an overall mean across study sites of 32.8 trees per hectare. This is considerably lower than the tree densities found in intact forests which are typically >300 trees/ha.

Tree species richness within individual pastures is generally low but the overall species richness present at the landscape level can be considerable. Of the 27 studies reporting speices richness, the overall landscape species richness ranged from 7 to 229, with a mean species richness of 66.7 per landscape. However, since the sampling methods and areas sampled varied across landscapes, these numbers are not directly comparable. A better comparison would be to generate species-areas curves comparing landscapes, but the information to generate these curves is lacking in most studies.

The trees present in pastures occur in a wide range of sizes. Mean tree heights ranged from 7.5 m to 26.2 m, with an overall mean of 13.3. The generally small diameters of most trees in pastures reflects the fact that many of these trees are pioneer species that have regenerated in the pastures subsequent to pasture establishment. The few large trees within these systems are generally remnant trees that have not yet been felled.

3. Effects of tree cover on pasture productivity

Livestock production from pastures is an important economic activity in Mesoamerica, not only because it ties up so much of the available land resources (**Table 7**) but also because of the rural employment it generates, the value of its products and their contribution to food supply (Rivas and Holman, 2005). Since most cattle production in the region is on converted forest land, it has been identified as a major cause of the loss of natural habitat and biodiversity.

Table 7. *Numbers of cattle and area of pasture in Mesoamerican countries.*

Country	Livestock inventory 2003, million heads	Area under permanent pastures, 2002, million ha	Pasture area as a proportion of total agricultural land use, %
Costa Rica	1.2	2.3	81.7
El Salvador	1.0	0.8	46.6
Guatemala	2.5	2.6	57.7
Honduras	1.9	1.5	51.4
Nicaragua	3.5	4.8	68.9
Panama	1.6	1.5	68.8
Colombia	25.0	41.8	90.8
Mexico	30.8	80.0	74.6

Source: FAOSTAT (2004)

The majority of this pastureland became impoverished as a result of overgrazing and soil compaction, uncontrolled burning and other activities inappropriate for the development of productive farming. This change in the use of the land has serious environmental consequences, including the loss of soil, biodiversity, availability of water and therefore social inequity.

Three common types of cattle production are found across the region: beef production, specialised dairy, and dual purpose (milk and beef). The three systems are distributed through different geographical regions (low, medium and high lands). Cattle systems depend on grazing, and pasture degradation is the main constraint to efficient and sustainable production. Quantity and quality of tropical grasses available for livestock, decreases during the dry season, which in many areas extends for 5 to 6 months with < 20 mm per month. This seasonal drought together with overgrazing leads to increasing land degradation and deforestation as farmers migrate to forested areas. Low water availability results both in low biomass availability from pasture (Cajas-Giron, 2002) and low digestibility and nutrient content in the available biomass, resulting in very low biological and economic efficiency.

Taking into account that the planting of trees in native and naturalised pastures has been increasingly recognized as a useful land use practice for income diversification (Mead, 1995), a conservation measure against loss of biodiversity and soil erosion (Young, 1997, Harvey and Haber, 1998) and as an enormous potential source for feeding animals in areas when a major constraint to higher productivity from ruminants is the low availability of good quality feeds, especially during the dry season and periods of drought (Aletor and Omodara, 1994).

The number of the studies found on trees and, pasture or livestock productivity in each country are shown in **Figure 4**. The majority of the papers were from Colombia and Costa Rica, and most (85%) were conducted at farm scale, with only 7% and 8% at landscape and plot level respectively.

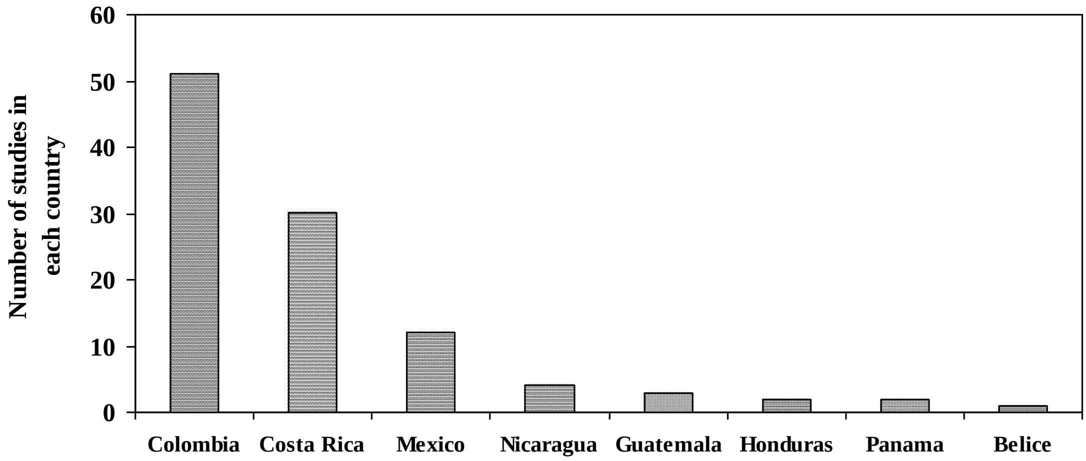


Figure 4. *Number of studies on trees and pasture or livestock production for each country in Mesoamerica.*

The majority of the studies were from grey literature (51.4%), nearly 5% were articles published in *Agroforestry Systems* or *Agricultural Systems*, 14% were published in the *Revista Agroforesteria en Las Americas*, and 30% were published in electronic journals (*Livestock Research for Rural Development* and *Revista Colombiana de Ciencias Pecuarias*).

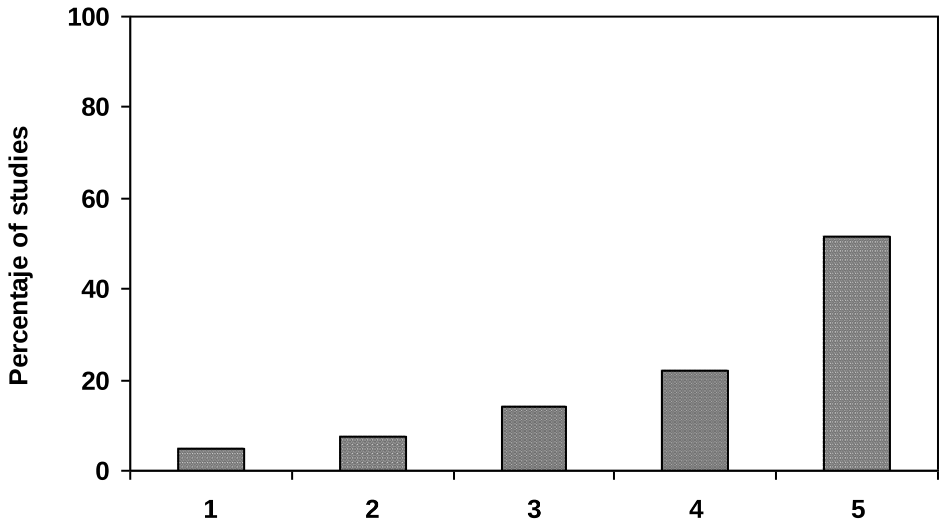


Figure 5. *Percentage of reviewed studies in different journals (1= Agroforestry Systems and Agricultural Systems; 2= Theses; 3= Revista Agroforesteria en Las Americas; 4= Journal of Livestock Research for Rural Development and Revista Colombiana de Ciencias Pecuarias; 5= Grey literature).*

3.1 Trees on pastures

Fodder trees as well as fuelwood and timber trees, including indigenous and naturalised species, are commonly found on paddocks across the region. They can be found as isolated trees, live fences, and in a few cases they have been planted as fodder banks. Four plant strata: pasture, leafy shrubs, arboreal (fruit producing) trees and emergent timber trees have been identified from inventory of trees on seasonally dry pastures in Colombia that have general relevance to the Mesoamerican region (Cajas and Sinclair, 2002). While there is inevitably some overlap amongst these strata, influenced by tree age and management (e.g. timber trees may produce fruit; shrub species, if not managed may grow into trees), the classification is helpful in understanding the main role of different trees and shrubs within the production system.

Trees on grasslands offer many benefits. Apart from their value as feed, many species are recognised for their multi-purpose contributions to the productivity of farming systems, to the welfare of people and to the protection of the environment. Trees on grasslands can be found ranging from small holders to large scale producers. Trees on grasslands can be found on all types of farms ranging from small holders to large scale producers. (Giraldo 2000; Cajas-Giron and Sinclair, 2001; Hernandez et al., 2002; Villanueva and Ibrahim, 2002, Villacis et al., 2003, Esquivel et al., 2003). Common tree fodder species found in Mesoamerica and Colombia are listed in **Table 8.**

Table 8. *Tree species most frequently found on pastures in Mesoamerica and their key utility and attributes.*

Species	Fodder	Pods/fruits	Timber	N-fixing	Deciduous	Evergreen
Leucaena ssp	√			√		√
Gliricidia spp	√			√	√	
Albizia saman	√	√	√		√	
Acacia penatula		√		√		√
Crescentia spp	√	√				√
Phitecellobium dulcis	√	√		√		√
Calliandra spp		√		√		√
Erythrina spp	√			√		√
Cassia grandis		√		√		√
Enterolobium cyclocarpum		√		√		√
Prosopis juliflora		√		√		√
Bursera simarruba			√			√
Brosimum alicastrum	√	√				√
Guazuma ulmifolia	√	√				√
Acacia decurrens	√		√	√		√

3.2 Primary productivity

Shrub and tree layer

Growth expressed as productivity of shoots, stems, leaf and reproductive organs (flowers and fruit) for shrub and tree fodder species on pasture were found to be scarse (Giraldo, 1999; Cajas-Giron, 2002; Esquivel, unpublished). Some papers on timber trees measured tree stem diameters and heights (Andrade, 1999; Jimenez et al., 2003). Most reported results correspond to a very short evaluation period (no longer than one year), and were carried out only for the first stages of growth (1 or 2 years after tree establishment). Some species such as *Gliricidia sepium*, *Leucaena leucocephala, Trichanthera igantean* and *Erythrina poepigiana* have been evaluated mostly for foliage production using fodder banks and life fences (Camero and Ibrahim, 1995, Romero et al. 1993, Mahecha et al., 1999; Jaramillo et al., 2002; CIPAV, 20002). Primary productivity in terms of fresh foliage from fodder banks and life fences of the studies reviewed range from 10 to 20 t ha^{-1}, but this depends on the species, tree height and number of cuttings. Due to the use of different units of measurement and different methods for evaluating biomass, and because most of the studies do not report dry matter content, it was not possible to compare these data.

Herbaceous components

The review of work on the grasslands on which cattle are raised reports an herbaceous layer of native and introduced tropical grass and legume species as the major resource for livestock systems (Ibrahim et al., 2000). In general, pastures have been established directly on land cleared from forest through slash and burn. Native (*Paspalum sp.*) and naturalised (*Bothriochloa sp., Dichanthium sp.,* and *Hyparrhenia rufa*) pasture species are most common. *Ischemum indicus* (retana) appears to be spreading rapidly in some areas (Szott et al., 2000). However, new genotypes of *Brachiaria* (*B. brizantha* cv marandu, *B. decumbens*, *B. brizantha* cv toledo, *Brachiaria humidicola* and *B. hybrids* I and II) and *Panicum* (*P. maximum* cv mombasa, and tanzania), that are better adapted to ecological conditions in tropical countries, have been selected and are now grown commercially (Argel and Keller-Grein, 1996).

Dry matter availability has generally been taken as the main indicator of the effects of fodder, timber or other woody species on pasture productivity. Several authors reported higher dry matter availability of pasture with trees than without, measured on grazed plots mainly using randomized quadrats as described in Botanal (Hargreaves and Kerr, 1992) or Frequency (Hoyos et al., 1992), and the comparative yield method for estimating dry matter yield of pasture (Haydock and Shaw, 1975). This means that the results reported are actually of standing biomass rather than productivity over time. There were no published papers that measured primary herbaceous productivity using repeated harvest of protected measurement areas or net photosynthesis. Therefore, measuring herbaceous primary productivity over seasonal cycles associated with trees on pastures is a key research priority.

Effect of trees on dry matter availability of herbaceous components

Several papers suggest that there are no detrimental effects of woody species on standing biomass of herbaceous species such as *Brachiaria brizantha* and *B. humidicola* (Andrade, 1999; Bolivar, 1998), *Panicum maximum* and *Bothriochloa pertusa* (Roncallo et al., 2000), *Cynodon plectostachyus* (Mahecha et al., 1999) or *Dichanthium aristatum* (Cajas-Giron, 2001). Fast growing trees of various species and types at an overall density of up to 625 trees ha^{-1} had no detectable effect on either pasture biomass or composition over a two year period, which, demostrated that high tree densities can be established in pasture without immediate reductions in pasture productivity (Cajas-Giron, 2002).

Improvements of quantity of dry matter of grass species in comparison with open grassland are reported to be in the order of 10 to 37%. The majority of the authors (i.e. Bolivar, 1998, Andrade, 1999, Mahecha et al., 1999) suggest that the increases in dry matter are due to the nitrogen supplied by woody legumes species. However, none of the studies made any measurements to substantiate this claim. As mentioned above, most of the studies are over a short evaluation period and correspond to one or two years after the trees have been planted. In some cases, pasture has been established in forestry plantations with larger trees, but these studies suffer from short evaluation periods and the lack of base line data for comparison. The growth curves of herbaceous components may be modified by different livetock stocking rates throughout the year, animal droppings can increase soil nitrogen content, which modifies grass production and botanical composition. Such modifications can cause important changes in forage quality and quantity, and consequently livestock behaviour and production may be modified. From the results of the reviewed studies it is difficult to make definitive conclusions in terms of the effects of trees on dry matter availability due to the lack of long term studies and research testing different interactions between factors that are involved in the system.

Very few studies were found in relation to measurements of effects of naturally regenerated tress on pasture although there are far more naturally regenerated than planted trees on Mesoamerican pastures. Casasola (2000) and Restrepo (2002) suggested that the presence of trees on pasture appears not to have a negative impact on dry matter availability. However, these studies compare different tree cover or vegetation categories within pastures rather than separate plots or paddocks with and without trees. Natural regeneration is the dominant means of converting open grassland to silvopastoral systems and so longer term studies should be planned to test the effects of different tree crown arquitecture on various grass and herbaceous legumes.

Effect of tree shade on pasture

Very few of the common grass species in Mesoamerica have been evaluated with resect to their shade tolerance (**Table 9**) and no data were found regarding shade tolerance of herbaceous legumes. None of the studies showed either the role of these species on pasture nor any interactions in relation to trees or livestock performance. Most of the studies listed only the presence of herbaceous legumes. The most commonly found were: *Centrosema pubecens, Desmodium spp, Desmodium distortum, Pueraria haseoloides, Teramnus spp, Arachis pintoi, Desmanthus virgatus, Rhynchosia minima, Vigna sp.*

Table 9. *Reported shade tolerance of some common Mesoamerican grass species*

	Shade tolerance level			Reference
	High	Medium	Low	
Paspalum conjugatum	√			(Aquino et al., 2004)
Brachiaria brizantha		√		(Andrade, 1999); (Zelada 1996)
Brachiaria decumbens		√		Andrade (1999)
Brachiaria humidicola		√		Aquino et al. (2004)
Panicum maximum		√		Andrade (1999); Zelada (1996)
Axonopus compressus	√			Zelada (1996)

Two studies report differences in dry matter availability under trees with different crown densities. Esquivel (in preparation), found in Cañas (dry Pacific side of Costa Rica) that dry matter availability during the wet season was reduced by 60-70% under dense crowned species such as *Guazuma ulmifolia* and *Enterolobium cyclocarpum* and between 15 and 20% under sparse crowns of *Cordia alliodora*, *Tabebuia rosea* and *Acrocomia aculeata* when compared with areas away from the crowns. Cajas-Giron et al.(in preperation), report that mean total dry matter under trees with sparse crowns (gliricidia, enterolobium, cassia, leucaena and albizia) was significantly higher (2.45 t ha^{-1}) than under trees (1.96 t ha^{-1}) with dense crowns (erythrina, clitoria, gmelina, pachira and guazuma) in seasonally dry pastures in the Caribbean region of Colombia. Grass species responded differently to different tree species. *Dichanthium aristatum* had higher dry matter availability under trees of dense crowns (0.5 t ha^{-1}) compared with tree species of sparse crowns (0.1 t ha^{-1}), while *Brachiaria mutica* showed higher dry matter availability under sparse crowns than in dense crowns (0.4 and 0.13 t ha^{-1} respectively) (Cajas-Giron et al., in preparation).

Effects of different tree shade on productivity of different pasture species and changes in botanical composition of pasture need to be further explored. Effects of tree shade on nutritive value of pasture as discussed under animal productivity below.

3.3 Animal productivity

Extensive research has been conducted on nutritive values (mainly crude protein and digestibility) of tree fodder (**Table 10**). The main objective of such research has been to asses the ability of tree fodder species to supply animal requirements especially in periods when herbaceous fodder is scarce. These studies suggest that tree fodder species are viable options for livestock diets and generally result in increased animal production. For example *Leucaena leucocephala,* the most commonly used and researched fodder shrub, is known to produce forage of high quality containing 28-40% crude protein with 54 to 70% digistibility (Roncallo et al., 2000; Cajas-Giron, 2002; Delgado Gomez et al., 2001). Very few studies were found on evaluation of rumen function, and included only *Enterolobium cyclocarpum* and *Sapindus saponaria.*

Table 10. *Reported nutritive value of some common tree fodder species in Mesoamerica.*

Species	Crude Protein %	Degradability %	Reference
Leucaena leucocephala	29.5	70.0	
Gliricidia sepium	26.0	79.0	Cajas-Giron (2002)
Albizia saman	25.3	56.0	
Crescentia cujete	16.7	80.0	
Cassia grandis	16.5	55.0	
Guazuma ulmifolia	15.6	67.0	
Erythrina poepigiana	24.2	51.4	
Phitecellobium dulce	24.1	59.6	Ibrahim et al
Calliandra calothyrsus	20.2	21.0 [1]	
Spondias purpura	16.5	56.6	
Enterolobium cyclocarpum	21.7	68.8	
Acacia decurrens	16.3	47.8[1/]	Galindo and Giraldo (2003)

[1 /] *Species with high tannin content, so degradability may be underestimated.*

Fruits and pods from trees are an important component of the animal diet especially during the dry season when pasture scarcity is the most important factor that constraints animal production. **Table 11** shows some nutritional values of fruits/pods that were found in the review. The protein content is given as the value of the whole pod or fruit but most of protein is contained in the seeds, although data on this are scarce.

Table 11. *Production of fruits or pods of tree fodder and some nutritive attributes.*

Species	Production (kg tree $^{-1}$)	Protein in the pod/fruit (%)	DMIVD(%)	Ca: P (%)	K (%)	Reference
Albizia saman	20-80	24.0	73.7	2.2:1	0.12	Baquero et al., 1998
P. juliflora	10-120	10.2	67.8	2:1		Roncallo et al., 1999
Enterolobium cyclocarpum		16.3	64.8			Hughes and Stewart, 1990
Guazuma ulmifolia	3-10[1]					Cajas-Giron, 2002
Acacia pennatula	2-15	13.0	46.8			Casasola, 2000
Senna atomaria	550-2550					Roncallo et al., 1995
Libidibia coriaria	10-13					
Acacia parnesiana		17.0				
Acrocomia aculeata	8.6	5.5	66.4			
Guazuma ulmifolia	26.4	7.5	62.8			Ibrahim et al (unpublished data)
Albizia saman	36.1	15.6	71.5			
Enterolobium cyclocarpum	86.0	13.12	67.8			

[1/] Trees of only 1 and 2 years old

Fruits and pods are used mainly as dietary supplements and farmers may harvest them to make homemade concentrate feeds. Increases in milk yield of more than one litre per cow per day, have been reported when the supplement included pods of *A. saman* and *Prosopis juliflora* (Roncallo et al., 2000; Jimenez et al., 2005). As fruits and pods are not hundred percent of the whole diet, it is not clear exactly how they contribuite to better animal performance; for this reason, studies including a greater number of fruits and pods from different tree species should be designed to have a better understanding of their role in animal production.

Tree shade may also induce changes in nutritive value of pasture. Higher concentrations of nitrogen and potassium, have been reported in herbaceous forage growing under trees than in open grasslands (Wilson and Ludlow, 1990). **Table 12** shows some nutritional parameters of grass species growing under an open pasture and with trees. Grasses growing with trees generally have higher quality than those in the open but it is not clear what causes these changes in nutritive quaility. Better understanding of how the presence of trees improves nutritive quality could improve planning of feed systems for grazing ruminant animals.

Table 12. *Changes in nutritional values of some grass species under shade.*

Grass Species	CP	DMIVD	NDF	ADF	CP	DMIVD	NDF	ADF	Reference
					%				
		Under shade				Open grasslands			
P. conjugatum	9		71		7.4		75.5		Aquino et al., (2004)
B. humidicola	7.6		77						Aquino et al., (2004)
B. dictyoneura	7.8		76						Aquino et al., (2004)
B. brizantha	9.5	52.5		42	8.2	50		49	Andrade, (1999)
B. brizantha	6.7	46.1	75		4.9	46	80		Esquivel (unpublished)

There were some papers reporting better quality of grasses in silvopastoral systems (i.e. Bustamante, 1991; Giraldo, 1999; Roncallo et al., 2000) that were not included in Table 10, because there was not information about grass sampling methodology, which makes it impossible to evaluate whether improvements of grass quality in silvopastoral systems was due to tree effects (shade, nutrient cyclying, nutrient uptake by grass species), or other factors that could be involved, (e.g. herbaceous legumes may be affecting the quality of pasture as well).

Milk production

The majority of reviewed papers that report inclusion of tree fodder (leaves or pods) as a significant proportion of total feed intake were conducted to evaluate effects on milk yield. Most of these studies were conducted on pen-fed or housed animals. Very few studies have been done on grazing animals browsing trees or shrubs species. However, either on housed or grazing animals, several authors report increased milk production due to inclusion of tree fodder (leaves or pods) with a basal diet, ranging from 8 to 30% more milk over that obtained on open grassland (Roncallo et al., 1999; Roncallo 2000, Giraldo, 2000, Sousa de Abreu et al., 2000; Camero et al., 2001; Cajas Giron et al., 2002). The benefit of tree fodder is most remarkable during the dry season. Milk yield per hectare can be increased around 40-50% when cattle are browsing tree fodder even though herbaceous biomass in the dry season decreased by more than 50% in comparison to that produced in the rainy season (Giraldo 2000; Roncallo et al., 2000; Cajas-Giron et al., 2002). Where milk production decreases in the dry season, the production level where tree fodder is available still exceeds those in open grasslands.

Shrub and tree fodder species are not only important as part of the diet but they play an important role reducing heat stress, that in the tropics is an important factor of animal performance. Trees provide natural shade that can reduce solar radiation interception and reduce high temperatures that may result in reduced feed intake by animals and heat stress. Shade may also modify animal behaviour. Despite the importance to this respect not much research has been done on physiological animal responses to tree shade and productive and reproductive performance of grazing animals exposed to heat in tropical climates. Souza (2000) reported improvement in animal comfort from tree shade in Central Costa Rica associated with lower rectal temperatures of cattle and an increase of more than a litre per cow per day in the dry season. While she attributes the increased milk yield in shaded over open paddocks to the reduction of heat stress that she measured, it is unclear whether pasture quality and/or browse were also responsible for some of the effect.

Live weight gain
Fewer studies were found showing a direct effect of tree fodder on live weight gain especially for beef production systems than milk yield. Restrepo (2002) evaluated live weight gain of heifers under three different tree cover on farms. Live weight was 14 and 13% higher in pasture with high tree cover than in medium and low tree cover. Jimenez and Velasco (2003) reported 43% more beef production during the dry season of steers under grazing and browsing of a multistrata systems (pasture, shrubs and arboreal species) in comparison with open grasslands and over the whole year 25% more beef was produced in a system of shrub and pasture than in open graslands. On grazing animals and substituing 50% of a commercial feed by *Acacia decurrens* fodder, live weight gain was 7% higher in comparison with heifers grazing and fed with a commercial supplement. In general the results included in the review showed a live weight gain that ranges from 0.60 to 0.95 kg per animal per day for animals with access to trees, which is much higher than that commonly found in animals grazing open grasslands of 0.20 to 0.35 kg per animal per day (Cardona, 1995; Jimenez and Velasco, 2003; Ibrahim et al., 2000; Restrepo et al., 2002; Cajas-Giron et al., 2004). There is a wide field to be explored on the effects of trees on grazing animals of beef breeds in several aspects. Quality of beef may be affected by the type of the diet provided by the shrub and tree fodder, and also by the heat stress reduction due to the tree shade.

Animal health and welfare
Shade reducing high temperatures and a more diverse diet available when trees are present on pastures may influence animal health and welfare. Effects of shade on reduction in heat stress are discussed above in terms of increased productivity but may also be seen to provide a welfare benefit. More diverse diets are expected to have positive impacts on health through various mechanisms. Condensed tanins, for example, which are usually present in tree fodder, seem to reduce abomasal and intestinal infections. Protein suplied by shrubs and tree fodder can be protected in the rumen by tanins and absorbed in the intestines, indirectly improving resitance to internal parasites. However, these asumptions have not yet been tested. Up to now, there are no data on the impact of browsing on animal health and welfare in Mesoamerica, which is increasingly important because national and international markets are demanding products with high biological quality and animal welfare standards.

A full bibliography of the papers on trees and productivity of pastures reviewed for this report is given in **Appendix 7**.

4. Animal diversity

There is a growing consensus that protected areas, in and of themselves, are insufficient to conserve the rich biodiversity present in the Mesoamerican biodiversity hotspot. Although protected areas are the keystone to all conservation efforts, they are often too small, too isolated and too heavily impacted by human activities to be fully effective in conserving species of concern. They also do not cover all of the different ecosystems and habitat types present within the region, with many ecosystems being sorely underrepresented within the protected area system. In addition, most of the protected areas within the region are immersed in a sea of agricultural and pastoral landscapes, effectively isolating animal populations within the boundaries of the protected areas and reducing their long-term viability. Many protected areas are also threatened by human activity on adjacent land, such as fire, grazing, pesticide contamination and hunting.

In order to ensure the long-term conservation of biodiversity in the region, it will be critical to extend conservation activities beyond the borders of the protected areas and into the surrounding agricultural landscapes. Large-scale conservation efforts are required that integrate conservation activities across protected areas and agricultural landscapes and manage landscapes for multiple functions (e.g., agricultural productivity, biodiversity conservation and rural livelihoods). Within the agricultural landscapes, key conservation issues include the provision of habitats and resources within the agricultural matrix, as well as the maintenance of landscape connectivity.

Recent studies have shown that the presence of forest and tree cover within agricultural landscapes can help contribute to the conservation of biodiversity at large spatial scales (e.g., Harvey et al. 2006). On-farm tree cover, such as small forest fragments, riparian forests, dispersed trees, live fences and fallows can provide important habitat and resources for wildlife, as well as serving as corridors or stepping stones that facilitate animal movement. However, despite the growing recognition of the contribution of forest and tree cover to the conservation of biodiversity in agricultural landscapes, there are few studies that have documented patterns of animal diversity within pasture-dominated landscapes and examined how differences in the type, spatial arrangement and availability in on-farm tree cover influence animal diversity. An understanding of the relationships between on-farm tree cover and animal diversity is critical for informing conservation efforts within agricultural landscapes. It is particularly relevant within the context of the Mesoamerican Biological Corridor which seeks to create linkages between existing, isolated protected areas by promoting forest conservation and better land use management in the agricultural landscapes that occur between protected areas, as many of these landscapes are dominated by pastures and agricultural areas.

The overall aim of this section is to review the knowledge of patterns of animal diversity within pasture-dominated landscapes and their relationships with on-farm tree cover. Specific objectives are 1) to identify the information available on animal diversity within pasture-dominated landscapes of Mesoamerica; and 2) to synthesize the key findings related to patterns of animal diversity in different land uses within pasture-dominated landscapes. The review method and overall database design are described in Sections 2.2 and 2.3 of this report so only the specific database aspects for animal diversity are outlined below.

4.1 Description of the database

The animal diversity page is designed to collect numerical and categorical data on animal biodiversity contained in each article. All information on animal diversity was divided by land use when such data existed. The primary numerical data we collected includes the mean and total species richness per land use; the mean and the total abundance; Shannon's index of diversity and evenness per land use. When information on feeding guilds existed, this data was included in a related database that collected the richness and abundance data mentioned above by feeding guild. We also collected information on the methods used in the study including the duration of the study (months), the total sampling effort (hours), the sampling effort per habitat (hours) and the sample season (rainy, dry or both). We included two categorical fields, "Type of Study" and "Methods used for study of animal diversity". The first recorded whether the study focused on species diversity, animal behavior, habitat use, demography, movement within the landscape, migration, biometrics, and whether it contains a species list or data on species abundance and frequency. The second, recorded methods used, such as point counts, mist nets, pitfall traps, baited traps, sweep nets, searches, or telemetry. The methods field also contains and open category for listing other methods used. As with the tree data, the animal data was entered by land use. A screenshot of the animal diversity page of the database is found in **Appendix 1**.

Notes on the presentation of data
This review presents the data in several ways, depending on the specific objective at hand. When providing information on the amount of information on a given topic, we generally present the number of publications concerning this topic (from a total of 60 articles). In contrast, when we provide information on the number of individual studies of animal taxa, we refer to a total of 65 studies, in which those papers with multiple taxa are recorded as multiple studies (one study per taxa). When we provide data on the methods used in different studies, the total numbers are greater than the number of studies or papers because several studies use multiple methods.

4.2 Information about animal diversity within pasture-dominated landscapes

A total of 60 papers provide information on animal diversity within pasture-dominated landscapes of Mesoamerica (**Appendix 8**). Of these, three are review papers that synthesize data that has already been published elsewhere (e.g., Harvey et al. 2005, Harvey et al. 2006). In addition, since a few studies appear to use the same data sets or portions of the same data set (e.g., Estrada et al. 1997 and Estrada and Coates-Estrada 2005; Estrada and Coates-Estrada 2002 and Estrada et al. 1998; papers by Graham et al.), the actual number of data sets is probably lower than the number of papers.

Location of animal diversity studies
Studies of animal diversity in pasture-dominated landscapes have been conducted in a wide range of ecosystem types, ranging from Tropical Dry Forest to Tropical Wet Forest (**Figure 6**). More than half of the studies come from either Mexico (26) or Costa Rica (18 studies). Nicaragua and Colombia are the next most-studied countries (with 7 and 6, studies respectively), other countries have only one (**Map 2**). Birds have been studied throughout the isthmus and studies of spiders and insects are also well distributed along the Mesoamerican land mass, but bats were studied only in Mexico, Nicaragua and Costa Rica and mammals and amphibians only in Mexico and Costa Rica.

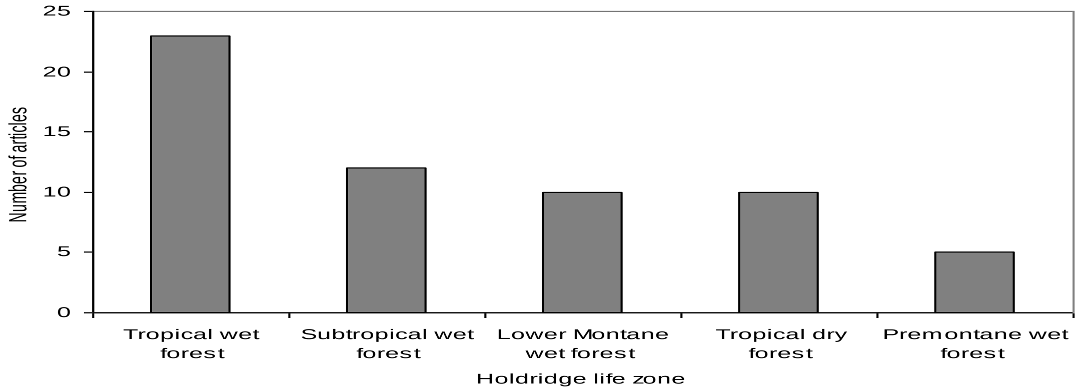
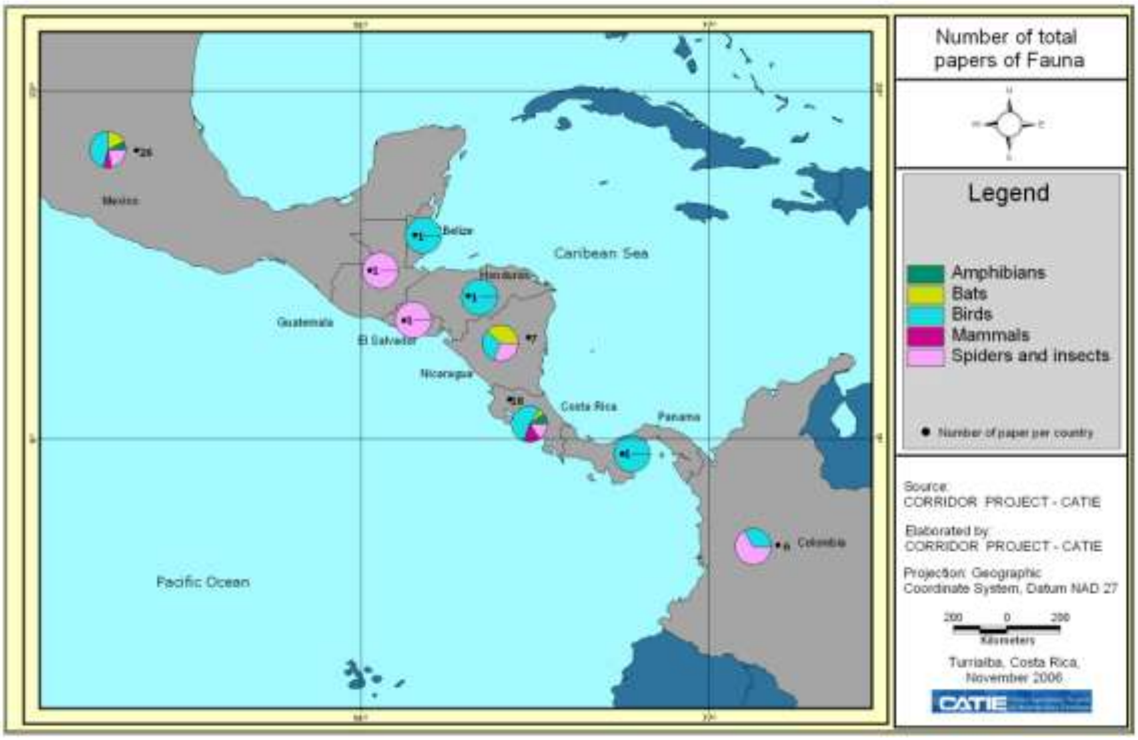


Figure 6. *Number of studies of animal diversity conducted in pasture-dominated landscapes in different life zones in Mesoamerica (n= 60 articles).*



Map 2. *Number of studies on different animal taxa in pastoral landscapes by country in Mesoamerica. Numbers indicate the total number of animal-related papers; the area of colours within circles is proportional to the number of papers of that taxa (see colour legend on map).*

As with studies of tree cover, most of these studies of animal diversity stem from only a handful of pastoral landscapes where particular projects and/or institutions are working (**Table 13**). The landscapes with the greatest number of studies of animal diversity are Los Tuxtlas, Mexico (17 studies), Rivas, Nicaragua (5 studies) and Las Cruces, Costa Rica (6 studies). Groups that have been particularly instrumental in documenting patterns of animal diversity include the UNAM group led by Alejandro Estrada (10 papers), the FRAGMENT[9] project (9 papers), and the Stanford Center for Conservation Biology group (4 papers).

***Table 13**. Summary of studies describing patterns of animal diversity in pastoral landscapes within different countries in the Mesoamerican region.*

Country	# of studies describing animal diversity in pastoral landscapes	Key landscapes studied	Key research institutions	Key scientific groups or projects that have already published information	Key groups or projects generating information not yet published
Belize	1				
Colombia	5	Zona Andina (quindio, Pereira), La Planada y Orinoquia	CIPAV, Instituto Alexander von Humbolt, Corpoica.	GEF-SPP project, Andes Project	GEF SPP project, Andes Project
Costa Rica	20	Las Cruces, Cañas, Rio Frio, Monteverde	CATIE, Stanford University, UNA	FRAGMENT, GEF-SSP, IGERT, Research group led by Gretchen Daily	FRAGMENT, GEF SSP projects
El Salvador	1				
Guatemala	1	Petén	CATIE		
Honduras	1	Copán	CATIE		BNPP[10]
Mexico	28	Chiapas, Los Tuxtlas-Veracruz	ECOSUR, UNAM, Instituto de Ecología, UNAM	Research group led by Alejandro Estrada; Research group led by Sergio Guevara and Javier Laborde	ECOSUR
Nicaragua	13	Muy Muy, Rivas, Matiguás	Fundacion Cocibolca, CATIE, UCA	FRAGMENT, GEF-SSP	FRAGMENT, GEF SSP, BNPP
Panama	1		CATIE		
Total	**70**				

In addition to the published articles, there is considerable additional information in theses and project reports which has not been published. For example, there are at least seven M.Sc. theses on animal diversity (birds, bats, dung beetles, amphibians and butterflies) in pasture-dominated landscapes in Costa Rica from the FRAGMENT project that have not yet been published[11]. Similarly, three-years worth of data on birds, molluscs, ants and butterflies that has been collected by the GEF- SSP project[12] in Colombia, Nicaragua and Esparza, Costa Rica is still under analysis and has not yet resulted in publications. In addition, the ongoing BNPP project[13] (Honduras and Nicaragua) and the Andes[14] Project (Colombia) are generating additional information on animal diversity in pasture-dominated landscapes which should become available during the next few years. Last, but not least, there is a book on "Evaluación y Conservación de Biodiversidad en Paisajes Fragmentados de Mesoamerica', edited by C. Harvey and J. Saenz, that will be published in early 2007 that contains at least 23 chapters from the region summarizing patterns of biodiversity in fragmented, agricultural landscapes- some of which are unpublished data sets, and others which synthesize across multiple data sets. A list of known, ongoing projects that are currently collecting or analyzing information on animal diversity within pastoral landscapes is included in **Table 13**.

[9] Developing methods and models for assessing the roles of trees in sustainaing farm productivity and conserving regional biodiversity, a project led by CATIE, University of Wales-Bangor, Nitlapan, University of Gőttingen, UNA and Fundación Cocibolca.
[10] 'Biodiversity Conservation and Sustainable Production in Tropical and Temperate Fragmented Landscapes', joint grant between the University of Idaho and CATIE, funded by the National Science Foundation.
[11] Theses by Maria Cepeda (dung beetles and butterflies); Jorge Montero (bats), Rachel Taylor (birds), Jose Luis Santivanez (birds), Diego Tobar (butterflies), Julian Garcia (amphibians) and Domenica Alarcon (bats)
[12] GEF SSP project= Regional integrated silvopastoral approaches to ecosystem management project
[13] 'Biodiversity Conservation and Sustainable Production in Tropical and Temperate Fragmented Landscapes', joint grant between the University of Idaho and CATIE, funded by the National Science Foundation.
[14] Andes project= Conservación y uso sostenible de la biodiversidad de los Andes colombianos-IAvH

Scope of the studies
Although there are some important differences across the 70 studies, the majority of the papers (> 90%) have the same overall objective: to characterize animal abundance and species richness occurring within pastures and/or other land uses present in the landscape and to compare across these different land uses or types of tree cover. A related objective is to compare the overall patterns of animal diversity within pastures with or without various forms of tree cover to that of intact forest (65 studies). Comparisons across different types of silvopastoral systems are also fairly common, with 37 studies comparing animal diversity in pastures with different levels of tree cover and 23 comparing animal diversity in pastures with that in live fences.

Only a handful of papers go beyond the characterization of animal diversity to consider other aspects, such as how animals behave, move or use the pastoral landscape. For example, the only papers that specifically consider animal movement within the pastoral landscape are Graham (2001a, 2001b), Cohen and Lindell (2004), Medina et al. (2006), Vaughan and Hawkins (1999), Williams and Vaughan (2001) and Powell and Bjork (2004). The studies by Graham (2001a, b), Powell and Bjork (2004), and Schlaepfer and Gavin (2001) are the only studies that specifically look at population dynamics (of toucans, bellbirds and lizards, respectively).

Animal taxa
Of the 60 papers, most present data on only a single taxonomic group. Four papers provide data two animal taxa, and two papers report on four animal taxa (**Table 14**). With the exception of one paper on soil microfauna (Decaėns et al. 2004), all of the studies of animal diversity focus on above-ground biodiversity. Birds are the most frequently-studied taxa (with 33 studies), followed by spiders and insects (19 studies) and bats (11 studies). Amphibians and reptiles have been much less frequently studied (**Figure 7)**.

Table 14. *Summary of the papers that compare different animal taxa within a pasture-dominated landscape.*

Citation	Landscape	Taxa studied
Estrada et al. 1998	Los Tuxtlas, Veracruz, Mexico	Dung beetles, Terrestrial mammals
Estrada and Coates-Estrada 2002.	Los Tuxtlas, Veracruz, Mexico	Dung beetles, bats
Harvey et al. 2005	Rivas, Nicaragua; Cañas, Costa Rica	Birds, bats, dung beetles, butterflies*
Harvey et al. 2006	Rivas, Nicaragua	Birds, bats, dung beetles, butterflies*
Hernández et al. 2003	Rivas, Nicaragua	Dung beetles and butterflies*
Schlaepfer and Gavin 2001	Las Cruces, Costa Rica	Lizard and amphibians
Urbina-Cardona et al. 2006	Los Tuxtlas, Veracruz	Amphibians, lizard and snakes.

* Dung beetle and butterfly data are the same for these two studies.

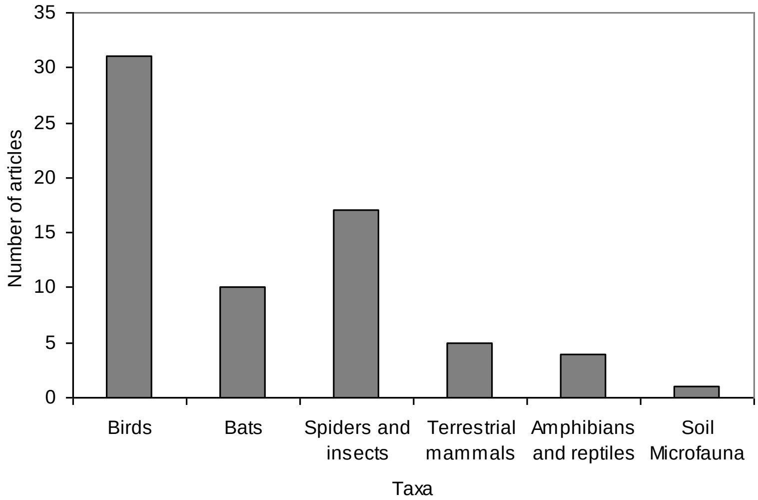


Figure 7. *Total numbers of articles that provide data on different animal taxa in pasture-dominated landscapes of Mesoamerica (n= 60 papers). Numbers do not add to 60 because several articles contain data on multiple taxa.*

Methods used to study animal diversity

Individual studies varied in the data they collected, with the specific data set reflecting the key objectives of the study. However, almost all studies provided information on species richness and species abundance or frequency, and specified in which habitats individual species were found (**Table 14**). Less than a quarter of the studies provided information on the demographics of animal populations within pasture-dominated landscapes. Similarly, few studies documented animal movement or migration within these landscapes, or provided biometric information on the individuals captured.

Table 14. *Number of articles about different topics for different animal taxa in pasture-dominated landscapes of Mesoamerica. Total number of articles is >60 because single articles may refer to more than one taxon.*

Taxa	Total number of articles	Species diversity	Species abundance or frequency	Animal movement within landscape	Animal behavior	Habitat use	Animal migration	Biometrics
Amphibians	3	3	3	0	0	3	0	1
Ants	4	4	4	0	1	4	1	0
Bats	9	9	9	0	5	8	1	2
Birds	30	26	26	4	19	28	12	1
Butterfly	4	4	4	0	2	4	0	0
Dung Beetles	10	10	10	0	6	9	1	2
Mammals	5	3	3	2	3	4	0	2
Reptilies	3	3	3	0	1	3	0	1
Soil microfauna	1	1	1	0	0	1	0	0
Spiders	1	1	1	0	0	1	0	0
Total	**70**	**64**	**64**	**6**	**37**	**65**	**15**	**9**

The methods used to assess animal diversity within pasture-dominated landscapes varied by taxa (**Table 15**). For example, all four studies that examined amphibians and/or reptile diversity used direct searches to find individuals, while all of the studies of bat diversity used mist-netting to capture bats. Birds were primarily sampled using point counts (22 of 30 articles), but 4 studies used mist nets and 2 studies placed radio transmitters on birds to follow bird movement. Non-flying mammals were sampled used a combination of baited traps, direct searches and, in one case, telemetry. Spiders and insects, on the other hand, were primarily sampled using pitfall traps (17 of 28 studies) specifically studies on ants and dung beetles, but other methods such as transects searches, bucket traps, fogging, tree beating and Winkler traps were also used. Details on the methods used in each of the individual 65 studies are provided in **Appendix 9**.

Table 15. *Summary of the different methods used in studies of animal diversity in pasture-dominated landscapes in Mesoamerica (n=70 studies). Note that because several studies used multiple methods, the sum of the cells exceeds 70.*

Taxa	Mist nets	Point counts	Bucket traps	Telemetry/ radio-tracking	Searches	Pitfall traps	Pyrethrin fogging and knockdown	Tree beating	Sherman trap - Tomahawk traps	Standard TSBF methods[1]
Bats	9									
Terrestrial mammals				1	3				1	
Birds	4	22		2	4					
Spiders and insects			1		4	13	1	2		
Soil microfauna										1
Amphibians and reptiles					4					
Total	**13**	**22**	**1**	**3**	**15**	**13**	**1**	**2**	**1**	**1**

[1]At each site, 10 samples of 25 cm×25 cm×30 cm were taken at regular 5 m intervals, along a line whose origin and direction were chosen at random.

Most of the studies used only a single method for each taxa. However, four studies on bird diversity (Guevara and Laborde 1993, Estrada et al. 1997, 2000; and Bojorges-Baños and López-Mata 2005.) used both point counts and mist nets to sample the bird community. These methods are considered complementary because point counts tend to be biased toward easily visible, large and canopy species, while mist nets tend to sample the understory species that are harder to detect visually. Among the other taxa, the use of multiple methods was rarer: only one study of spiders (Pinkus-Rendón et al. 2006) and one study of terrestrial mammals (Williams and Vaughan 2001) used multiple methods.

In addition to differences in the methods used to characterize the animals present, the sampling strategies varied significantly with respect to the sampling strategy and sampling intensity. Although most studies characterized animal diversity in two or more types of habitats within pasture-dominated landscapes, the number of plots or transects per habitat type and per landscape were highly variable, with some landscapes being sampled intensively and others only superficially. The majority of the studies were conducted at the plot level (35 studies), but 32 were conducted at larger spatial scales, either at the farm level (1) or more commonly, at the landscape level (25).

In addition, individual studies varied greatly in duration: of the 70 studies of animal taxa, 20 provided data collected in only a single season, 48 provided data from a single year, and only 2 provided data from multiple years. Similarly, individual studies of the same taxa vary greatly in their overall sampling effort, with studies differing by as much as an order of magnitude in their sampling effort (**Table 16**).

Table 16. *Variation in the total sampling effort in different studies by taxon.*

Taxa	# of studies	Total sampling per study (hours)
Amphibians	3	345-673
Ants	4	210-1152
Bats	10	96- 6121
Birds	31	47-1636
Terrestrial mammals	5	594-1896

Land uses in which animal diversity has been characterized

Studies on animal diversity were conducted in a variety of different land uses within pasture-dominated landscapes, ranging from forest fragments, to forest fallows (charrals) to pastures with dispersed trees. The most commonly surveyed habitat type were different types of pastures (38 studies of pastures with trees, 21 in pastures with an unspecified tree component and eight in pastures without trees) and secondary forests (43 studies), however over 40% of the studies also examined animal diversity in live fences, riparian forests, primary forests and perennial crops (**Figure 8**). On average, each study contained information on animal diversity in four land uses (range: 1-7).

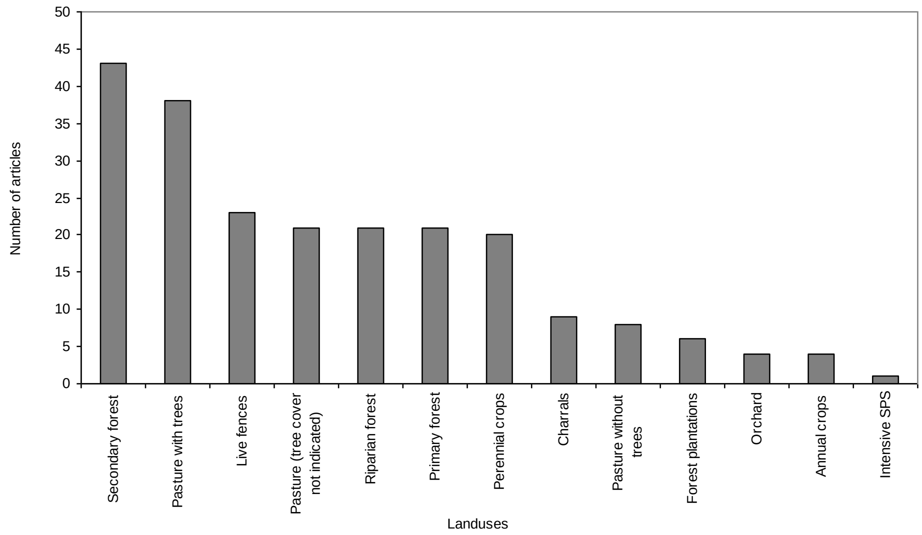


Figure 8. *Number of studies of animal diversity in different land uses present in pastoral landscapes of Mesoamerica (n= 60 studies).*

4.3. Patterns of animal diversity in pasture-dominated landscapes

Because the different studies of animal diversity are so variable (in their sampling design, sampling intensity, methods, taxa, duration and spatial scale), it is not possible to compare results directly across studies or conduct any rigorous statistical meta analyses across sites. Instead, we provide a list of some of the key results that have emerged in individual studies. While many of these results appear to hold true across a number of different studies, additional work is needed before they can be considered broad generalizations.

Key results

1) *Pasture-dominated landscapes with a heterogeneous tree cover can support a significant number of animal species.* For example, as many as 54 amphibian species, 92 ant species, 39 bat species, 226 bird species, 50 butterfly species, 36 dung beetle species, 33 reptiles, 39 mammals and 115 species of spiders have been identified in individual pasture-dominated landscapes (**Table 17**).

Table 17. *Total number of species recorded in different pasture-dominated landscapes in Mesoamerica.*

Taxa	Total number of species caught/registered
Amphibians	11-54
Ants	18-92
Bats	17-39
Birds	23-226
Butterflies	50-?
Dung beetles	17-36
Reptilia	7-33
Mammals	26-39
Spiders	115

2) *Many animal species observed in pasture dominated landscapes are generalist species that have adapted to agricultural disturbance, rather than more forest dependent species.* Numerous studies (e.g., Harvey et al. 2006, Medina et al. 2004, Vilchez et al. 2004) highlight the dominance of generalist species within the animal communities that occur in pasture-dominated landscapes. Forest-dependent species often occur, but in low abundances (Harvey et al. 2006; Ricketts et al. 2001; Estrada and Coates-Estrada 2005).

3) *Individual types of tree cover within the pasture-dominated landscape may vary in their importance for different animal taxa (as reflected in the numbers of individuals, numbers of species or species composition).* Studies which have compared animal diversity in multiple land uses (e.g., Estrada et al, Harvey et al. 2006, Daily et al., among others) have generally reported differences in species richness, abundance, diversity and composition across different land uses. In many cases, species richness and diversity are greatest in the more-forest like habitats, but this is not always true. Overall patterns seem to vary by taxa, by landscape and by study.

4) *Individual taxa vary in their responses to different types of habitats and tree cover.* So, for example, in Rivas, Nicaragua (Harvey et. al., 2006) the greatest bird species richness and abundance was associated with land cover types with high tree cover (secondary and riparian forests, forest fallows and pastures with high tree cover), whereas, bat species richness and abundance was greatest in linear tree features (riparian forests and live fences). So while there were some common patterns, in that riparian forests were important for both birds and bats, and pastures with low tree cover had the lowest abundance of both taxa, secondary forests and fallows were important for birds while live fences were important for bats.

5) *Forest-dependent species are more likely to be associated with forest-like habitats (secondary forests, riparian forests, charrals, etc.) than with the pasture-like habitats.* It is clear that different forms of tree cover retained in pasture landscapes retain different elements of forest habitat. So, isolated trees in an intensively grazed pasture do not replicate forest understorey habitat and while they may host canopy species and tree creeping birds they are unlikely to host understorey species adapted to the forest interior. Fire and cattle ingress into riparian and secondary forest within pasture dominated landscapes often results in loss of potential understorey habitat.

6) *Pastures with high densities of trees frequently have greater animal diversity than pastures with low tree densities.* The multi-taxa study by Harvey et al. (2006) clearly illustrated greater species richness of birds, bats and butterflies in pastures with high tree cover, compared to pastures with low tree cover. Galindo-Gonzalez and Sosa (2003) similarly postulate that greater tree density in pastures contributes to greater bat diversity, and numerous authors highlight the role of tree density

7) *The presence of live fences and dispersed trees make the pasture matrix more permeable to animals*, facilitating movement of some animal species from forest fragments into the agricultural landscape or across the matrix to other forests. A growing number of studies have documented birds (Lang et al. 2004, Luck and Daily 2003, Hughes 2002) and bats (Medina et al. 2006, Estrada and Coate-Estrada 2001, 2002l Galindo-Gonzalez and Sosa 2003) visiting live fences and using them to move across the agricultural matrix, indicating their importance as landscape linkages.

8) *Some animal species move frequently across the pastoral matrix and seem to be readily able to access the available resources and habitats within the matrix.* For example, the study by Medina et al. (2007) reported movement of bats between all types of tree cover (forest fragments, live fences, pastures with trees and riparian forests) present within a pastoral landscape in Nicaragua. Similarly, Guevara and Laborde (1993) documented 47 bird species of frugivores flying across open pastures to visit isolated trees. Graham (2001) reported movement of toucans in fragmented landscape was influenced by fruit abundance in pastures.

9) *The animal communities occurring within the agricultural landscapes are a subset of the communities in the adjacent forests*, with the major differences being that the agricultural communities are dominated by generalist species, have fewer forest-dependent individuals (they may retain many forest species, but in low abundances), and may exhibit greater dominance of a few species.

10) *The management of on-farm tree cover can influence the conservation value of this tree cover.* For example, a study of birds in live fences of Rio Frio, Costa Rica by Lang et al. (2004) found that live fences that are large and well-developed tree canopies had

significantly more bird species (81 spp.) than those that were small and recently pollarded (45 spp).

4.4 Limitations of available data on animal diversity and tree cover

Although there is a rapidly-growing number of studies of animal diversity within pasture-dominated landscapes, there is still insufficient information to clearly link patterns of animal diversity and species composition to different land uses and different levels (or spatial arrangements) of tree cover, making it difficult to assess how much tree cover of what types of tree cover are most compatible with biodiversity conservation and how this tree cover should be arranged within the landscape.

There are four key obstacles to understanding the relationships between on-farm tree cover and animal biodiversity in pasture-dominated landscapes.

First, there are simply not enough studies of animal diversity across different types of tree cover, different spatial arrangements of tree cover, or landscapes with varying patterns of tree cover. Although the number of studies has risen dramatically in the last five years, the information on different taxa is sporadic and incomplete, with most studies being single, one-time characterizations of a given taxa in a particular landscape. For most taxa, there are less than five studies available and even for birds (the best-characterized taxa) the information is far from complete (with little information on survival rates, movement, and habitat use, for example). Not only are there few studies, but these studies have tended to focus on only a handful of sites (particularly Las Tuxtlas, the FRAGMENT sites and Las Cruces) and many countries have had little, if any, studies on animal diversity outside protected areas. Additional information is needed for a much larger number of animal taxa across a much broader array of landscapes. In particular, information is woefully missing for below-ground taxa and many insect groups (excluding dung beetles which have been reasonably well sampled). From a country-level perspective, information is particularly scarce in Belize, Panama, El Salvador and Guatemala.

Second, there are no common methodologies across studies, making it difficult to compare and interpret results from different areas. Individual studies vary in the methods used to sample organisms, and even within studies of the same taxa, there are no standardized methods used. Individual studies vary in the methods used to sample different taxa and even in the application of these methods. For example, although most bird surveys are conducted with point counts, the location of point counts within the landscape, the spacing between point counts and the length of observation vary across studies. Studies also vary in the sampling intensity, plot size, number of plots, plot selection, timing and duration of the study, among other factors. They also differ in the types of information collected, with some studies providing only the bare minimum data on species abundance and species richness, while other studies provide more detailed information on behavior, demography and movement. In addition, studies vary in the land uses sampled, as well as in the way in which they define these land uses- making it difficult to know whether the ‘secondary forests’ mentioned in one site are equivalent to ‘areas of young growth’ or ‘abandoned fields’ in another. The types of information that should be routinely collected within studies of animal diversity in pasture-dominate landscapes are set out in the data collection protocol (Deliverable 3).

Third, another limitation is the lack of information on animal behavior and movement within agricultural landscapes, as well as the dynamics of animal populations. To date, the vast majority of studies of animal diversity in agricultural landscapes focus solely on describing the animal community within specific land uses or a specific landscape, at a given point in time, with basic information provided on the species present and their relative abundances. These studies, in and of themselves, indicate which species are present within the landscape, but do not provide any insight into the degree to which these species use, or depend on, the landscape, which resources within the agricultural landscapes they are taking advantage of, and whether individual populations are self-sustaining over the long-term or whether these are population sinks. Without long-term studies of how animals use and move within agricultural landscapes, it will be difficult to identify what features of landscapes are important for their continued survival. Similarly, without demographic studies, the long-term viability of populations and the stability of communities remains unclear.

A fourth and final problem with data currently available, is that few studies directly link patterns of animal diversity directly to the type, abundance or spatial arrangement of on-farm tree cover. Although it is well established in the ecological literature that animal diversity is often highly correlated to tree and plant diversity, few studies provide information on floristic and structural diversity of the land uses surveyed or attempt to relate vegetative characteristics to animal species richness, diversity or composition. In addition, there is remarkably little information on which tree species within different land uses in the agricultural landscapes provide key resources for different species and can help support wildlife populations. Similarly, although it is clear that the spatial arrangement of land uses and tree cover within the agricultural landscapes will impact the animal species present, very few studies provide detailed information on the structure and composition of the landscapes in which the studies were conducted, and even fewer explore the impact of landscape structure and composition on animal diversity (but see Ricketts et al., 2001 and Luck and Daily, 2003). In particular, there are no studies that have directly considered the impact of landscape connectivity on animal populations, even though connectivity is likely to be a key factor structuring animal communities. Last, but not least, there are no studies that have identified thresholds of either the amount or degree of connectivity of forest and tree cover for different animal groups. This is, in part, due to logistical constraints because this type of research would require sampling over multiple landscapes with differing degrees of tree cover and/or connectivity, which would be very costly and time-consuming.

Research needs

Although the numbers of studies on animal diversity in pasture-dominated landscapes has increased significantly in the last five years with 51 of the 60 publications having been produced in this time period), our understanding of the patterns and dynamics of animal populations and communities within pasture-dominated landscapes is still far from complete. Not only are there clear gaps in which taxa have been studied (with almost no information on below-ground biodiversity), but many basic questions about the long-term viability of animal populations within pasture dominated landscapes and the conservation value of these landscapes remain only partially understood.

First, there is a need to better understand how different animal taxa respond to the same pastoral landscape and what the conservation implications of these differences are.

- On the one hand, there is a need for more studies of individual taxa (using standardized and comparable methods) across different landscapes, to determine if individual taxa always exhibit the same responses to different types of tree cover and land use, regardless of landscape context, or whether these patterns are highly landscape-specific.
- On the other hand, there is also an urgent need for more multi-taxa studies within the same landscape to determine to what extent different taxa respond in similar (or distinct) ways to different types of tree cover occurring within the same landscape.

Second, there is a need to better understand how individual animals and populations use pastoral landscapes and on-farm tree cover, and so identify which types of tree cover and which species, are critical for maintaining a rich animal diversity within the agricultural landscape. This should include research on how both historical and current land management influences patterns of animal abundance, diversity and distribution.

Third, there is a need for long-term studies of the dynamics of animal populations and community changes, to understand the viability of individual populations and the stability (or dynamism) of animal communities within silvopastoral landscapes

Fourth, there is pressing need to explore the relationships between the structure and composition of the agricultural landscape and the patterns of animal diversity, requiring large-scale and co-ordinated research. This should include looking for thresholds of forest and/or tree cover and their connectivity that are required to maintain animal populations.

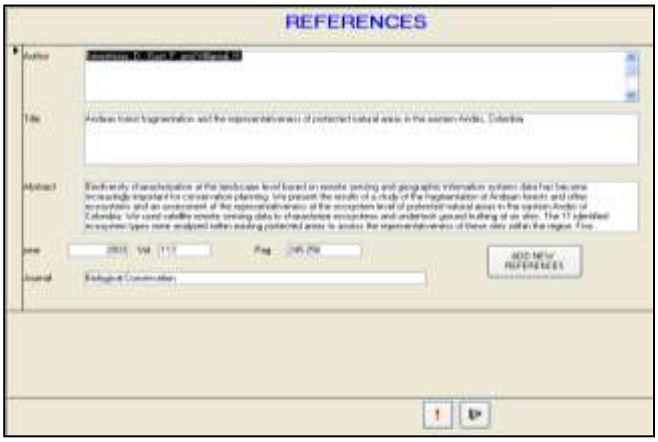
Acknowledgements

The authors of this report wish to acknowledge the participants of the CORRIDOR silvopastoral workshop held at CATIE 21-28 August 2006, for their inputs to various aspects of this report.

Appendix 1. Database in Microsoft Access 2000 for PC. 1) Forms referring to the manuscript's general themes and topic 2) Form of references, 3) Forms referring to tree cover in pastures and pastoral landscapes, and 4) Forms referring to animal biodiversity in pastures and pasture landscapes.

1

2



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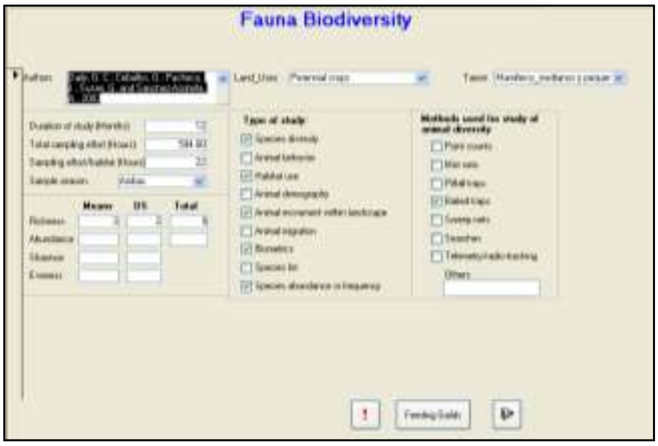

Appendix 2. Summary of the pasture-dominated landscapes in which tree cover was studied, by Holdridge life zone.

Area	Holdrige_Life_zone	Country	# of studies on flora
Aranzazu, Caldas.	Lower Montane wet forest	Colombia	1
Florencia, Caquetá.	Tropical wet forest	Colombia	1
Caribbean Microregion, Litoral, Sabanas, Golfo de Morrosquillo y Valle del Zinu.	Tropical Dry Forests	Colombia	1
Filandia, Quindio and Pereira, Risaralda	Lower Montane wet forest	Colombia	1
Ranch Farm (CRQ), Pijao, quindío	Montane pluvial forest	Colombia	1
Bellavista, El Dovio, Valle del Cauca	Premontane wet forest	Colombia	1
Colombia total			**6**
Cañas	Tropical Dry Forests	Costa Rica	6
Cordillera Tilaran Monteverde, Puntarenas	Lower Montane wet forest	Costa Rica	6
Esparza	Subtropical wet forest	Costa Rica	1
Finca la Suerte, 13 km northwest of the town of Cariari.	Tropical wet forest	Costa Rica	2
Guaira Annex of La Selva Biological Station, Sarapiquí.	Tropical wet forest	Costa Rica	1
Guapiles	Tropical wet forest	Costa Rica	1
La Culebra, San Carlos.	Tropical wet forest	Costa Rica	1
La Fortuna, San Carlos.	Premontane wet forest	Costa Rica	1
Las Alturas, Coto Brus.	Lower Montane wet forest	Costa Rica	6
Las Cruces, Coto Brus	Subtropical wet forest	Costa Rica	6
Los Santos and Río Macho Forest Reserves, Cordillera de Talamanca	Montane pluvial forest	Costa Rica	1
NP Palo Verde and BR Lomas Barbudal, Guanacaste	Tropical Dry Forests	Costa Rica	1
Puerto Jimenez y la Palma , Peninzula de Osa.	Tropical wet forest	Costa Rica	3
Puerto Jimenez, Peninzula de Osa.	Tropical wet forest	Costa Rica	1
Quepos, Puntarenas	Tropical Dry Forests	Costa Rica	1
Rio Frio	Tropical wet forest	Costa Rica	5
San Luis Valley, Guanacaste.	Tropical Dry Forests	Costa Rica	1
Volvan BARU, San Vito de Coto Brus,	Premontane wet forest	Costa Rica	1
Western slope of the Volcán Barva	Lower Montane wet forest	Costa Rica	1
Costa Rica total			**46**

Appendix 2 Continued. Summary of the pasture-dominated landscapes in which tree cover was studied, by Holdridge life zone.

Area	Holdrige_Life_zone	Country	# of studies on flora
Reserva Biosfera Maya, Peten	Subtropical wet forest	Guatemala	1
Guatemala total			**1**
Pico Bonito National Park, Honduras	Subtropical wet forest	Honduras	2
Honduras Total			**2**
Chajul Biological Station, Montes Azules Biosphere Reserve (MABR), Chiapas.	Tropical Dry Forests	Mexico	1
Ocosingo Valley, Chiapas	Tropical wet forest	Mexico	1
Pacific Coastal Plain of Chiapas.	Tropical Dry Forests	Mexico	1
San Fernando, Chiapas.	Tropical wet forest	Mexico	1
Ejido San Mateo near Chamela, Jalisco.	Tropical Dry Forests	Mexico	1
Centro de investigaciones costeras La Mancha (CICOLMA), Veracruz	Subtropical wet forest	Mexico	2
Los Tuxtlas, Veracruz.	Tropical wet forest	Mexico	16
San Andrés Tlalnelhuayocan, Veracruz.	Lower Montane wet forest	Mexico	1
La Antigua River basin, Xalapa - Veracruz.	Tropical wet forest	Mexico	1
Center for Technical Development TANTAKIN, Yucatan.	Tropical Dry Forests	Mexico	1
Mexico total			**26**
Boaco (Mpios Camoapa, San Lorenzo, teustepe y Boaco)	Tropical wet forest	Nicaragua	2
Protected area Miraflor-Moropotente, Estelí,	Subtropical wet forest	Nicaragua	1
Matiguas, Matagalpa.	Subtropical wet forest	Nicaragua	2
Rivas, Belen	Tropical Dry Forests	Nicaragua	7
Nicaragua total			**12**
La Pavas, Canal de Panama.	Premontane wet forest	Panama	2
Chiriqui, Bugaba, Santa Marta (30 km2), Santo Domingo (51 km2) y Sortová (35 km2)	Tropical wet forest	Panama	1
Panama Total			**3**
Total			**96**

Appendix 3. Summary of the land uses in pastoral landscapes of Central America in which tree cover has been characterized.

Country	Area	Holdridge Life zone	Pasture (tree cover not indicated)	Pasture without trees	Pasture with trees	Intensive SPS	Live fences	Charrals	Forest plantations	Riparian forest	Secondary forest	Primary forest	Orchard	Annual crops	Perennial crops	Total	Reference
Colombia	Caribbean Microregion, Litoral, Sabanas, Golfo de Morrosquillo y Valle del Zinu	Tropical Dry Forests	NA	NA	X	X	NA	NA	NA	NA	NA	NA	NA	NA	NA	2	Cajas-Giron and Sinclair 2001.
Colombia	Bellavista, El Dovio, Valle del Cauca	Premontane wet forest	NA	X	X	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2	Esquivel-Sheik and Calle Diaz 2002.
Colombia	Filandia, Quindio and Pereira, Risaralda	Lower Montane wet forest	X	NA	NA	NA	NA	NA	X	X	X	X	NA	NA	NA	5	Mendoza et al. 2005
Colombia	Aranzazu, Caldas	Lower Montane wet forest	NA	NA	X	X	X	NA	NA	NA	X	X	NA	NA	X	6	Otero et al. 2006.
Colombia	Ranch Farm (CRQ), Pijao, quindío	Montane pluvial forest	NA	NA	X	NA	NA	NA	X	NA	NA	NA	NA	NA	NA	2	Posada et al. 2000
Colombia	Florencia, Caquetá.	Tropical wet forest	X	NA	NA	X	NA	NA	NA	NA	X	X	NA	NA	NA	4	Ramírez 2002.
Costa Rica	Western slope of the Volcán Barba	Lower Montane wet forest	X	NA	NA	NA	NA	NA	NA	NA	X	NA	NA	NA	NA	2	Barrantes and Pereira 2002.
Costa Rica	Quepos, Puntarenas	Tropical Dry Forests	NA	NA	NA	X	NA	NA	NA	NA	NA	NA	NA	NA	X	2	Berninger and Salas 2003.
Costa Rica	Esparza	Subtropical wet forest	NA	NA	X	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1	Camargo et al. 2000.
Costa Rica	Guapiles	Tropical wet forest	NA	NA	X	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1	Camargo et al. 2000.
Costa Rica	Cañas	Tropical Dry Forests	NA	NA	X	NA	X	X	NA	X	X	NA	NA	NA	NA	5	Cárdenas et al. 2003.
Costa Rica	Las Cruces, Coto Brus	Subtropical wet forest	NA	X	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1	Carpenter et al. 2004a.
Costa Rica	Las Cruces, Coto Brus	Subtropical wet forest	NA	NA	X	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1	Carpenter et al. 2004b

Appendix 3 Continued. Summary of the land uses in pastoral landscapes of Central America in which tree cover has been characterized.

Country	Area	Holdridge Life zone	Pasture (tree cover not indicated)	Pasture without trees	Pasture with trees	Intensive SPS	Live fences	Charrals	Forest plantations	Riparian forest	Secondary forest	Primary forest	Orchard	Annual crops	Perennial crops	Total	Reference
Costa Rica	Rio Frio	Tropical wet forest	NA	NA	X	NA	X	NA	NA	NA	X	NA	NA	NA	NA	3	Chacon-L and Harvey 2005
Costa Rica	Cañas	Tropical Dry Forests	NA	NA	X	NA	NA	NA	NA	X	NA	NA	NA	X	X	4	Esquivel et al. 2003.
Costa Rica	Cañas	Tropical Dry Forests	NA	NA	X	NA	NA	NA	NA	NA	NA	NA	NA	X	NA	2	Ghazoul and McLeish 2001.
Costa Rica	Cordillera Tilaran Monteverde, Puntarenas	Lower Montane wet forest	NA	NA	NA	NA	X	NA	NA	NA	X	NA	NA	NA	NA	2	Harvey 2000a.
Costa Rica	Cordillera Tilaran Monteverde, Puntarenas	Lower Montane wet forest	NA	NA	X	NA	X	NA	NA	NA	NA	NA	NA	NA	NA	2	Harvey 2000b.
Costa Rica	Cordillera Tilaran Monteverde, Puntarenas	Lower Montane wet forest	X	NA	X	NA	X	NA	NA	NA	X	X	X	NA	NA	6	Harvey and Haber 1999.
Costa Rica	Cordillera Tilaran Monteverde, Puntarenas	Lower Montane wet forest	NA	NA	X	NA	NA	NA	NA	NA	X	X	NA	NA	NA	3	Harvey et al. 1999.
Costa Rica	Cañas	Tropical Dry Forests	NA	NA	X	NA	X	X	NA	X	X	NA	NA	NA	NA	5	Harvey et al. 2005
Costa Rica	Rio Frio	Tropical wet forest	NA	NA	X	NA	X	X	NA	X	X	NA	NA	NA	NA	5	Harvey et al. 2005
Costa Rica	Puerto Jimenez, Peninzula de Osa.	Tropical wet forest	X	NA	NA	NA	NA	NA	X	NA	NA	NA	NA	NA	NA	2	Healey and Gara 2003.
Costa Rica	Las Alturas, Coto Brus.	Lower Montane wet forest	NA	NA	X	NA	NA	NA	NA	NA	NA	X	NA	NA	X	3	Holl 1998.

Appendix 3 Continued. Summary of the land uses in pastoral landscapes of Central America in which tree cover has been characterized.

Country	Area	Holdridge Life zone	Pasture (tree cover not indicated)	Pasture without trees	Pasture with trees	Intensive SPS	Live fences	Charrals	Forest plantations	Riparian forest	Secondary forest	Primary forest	Orchard	Annual crops	Perennial crops	Total	Reference
Costa Rica	Las Alturas, Coto Brus.	Lower Montane wet forest	X	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	X	Holl 2002.
Costa Rica	Las Alturas, Coto Brus.	Lower Montane wet forest	X	NA	X	NA	NA	NA	NA	NA	X	NA	NA	NA	NA	3	Holl and Lulow 1997.
Costa Rica	Las Alturas, Coto Brus.	Lower Montane wet forest	NA	NA	X	NA	NA	NA	NA	NA	NA	X	NA	NA	NA	2	Holl and Quiros-Nietzen 1999.
Costa Rica	Las Alturas, Coto Brus.	Lower Montane wet forest	X	NA	NA	NA	NA	NA	NA	NA	X	X	NA	NA	NA	3	Holl et al 2000.
Costa Rica	Las Cruces, Coto Brus	Subtropical wet forest	X	NA	NA	NA	NA	NA	NA	NA	NA	X	NA	NA	NA	2	Jones et al. 2003
Costa Rica	Rio Frio	Tropical wet forest	NA	NA	NA	NA	X	NA	NA	NA	NA	NA	NA	NA	NA	X	Lang et al. 2003
Costa Rica	Las Alturas, Coto Brus.	Lower Montane wet forest	X	NA	NA	NA	NA	NA	NA	NA	X	NA	NA	NA	X	3	Lindell et al. 2004
Costa Rica	Las Cruces, Coto Brus	Subtropical wet forest	NA	NA	X	NA	NA	NA	NA	NA	X	NA	NA	X	NA	3	Luck and Daily 2003.
Costa Rica	Puerto _Jimenez y la Palma , Peninzula de Osa.	Tropical wet forest	X	NA	NA	NA	NA	NA	X	X	X	NA	NA	NA	X	5	Mayfield and Daily 2005.
Costa Rica	Puerto _Jimenez y la Palma , Peninzula de Osa.	Tropical wet forest	X	NA	NA	NA	NA	NA	X	NA	NA	X	NA	NA	X	4	Mayfield et al. 2005.
Costa Rica	Puerto _Jimenez y la Palma , Peninzula de Osa.	Tropical wet forest	X	NA	NA	NA	NA	NA	NA	NA	NA	X	NA	NA	NA	2	Mayfield et al. 2006.
Costa Rica	Guaira Annex of La Selva Biological Station, Sarapiquí.	Tropical wet forest	X	NA	NA	X	NA	NA	NA	NA	NA	NA	NA	NA	NA	2	Montagnini et al. 2003.

Appendix 3 Continued Summary of the land uses in pastoral landscapes of Central America in which tree cover has been characterized.

Country	Area	Holdridge Life zone	Pasture (tree cover not indicated)	Pasture without trees	Pasture with trees	Intensive SPS	Live fences	Charrals	Forest plantations	Riparian forest	Secondary forest	Primary forest	Orchard	Annual crops	Perennial crops	Total	Reference
Costa Rica	La Culebra, San Carlos.	Tropical wet forest	NA	NA	X	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1	Moulaert et al. 2002.
Costa Rica	Cañas	Tropical Dry Forests	NA	NA	X	NA	X	NA	NA	NA	NA	NA	NA	NA	NA	2	Muñoz et al. 2003
Costa Rica	Rio Frio	Tropical wet forest	NA	NA	X	NA	X	NA	NA	NA	NA	NA	NA	NA	NA	2	Muñoz et al. 2003
Costa Rica	Volvan BARU, San Vito de Coto Brus,	Premontane wet forest	X	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	X	NA	2	Nichols et al. 2001.
Costa Rica	Los Santos and Río Macho Forest Reserves, Cordillera de Talamanca	Montane pluvial forest	X	NA	NA	NA	NA	X	NA	NA	X	NA	X	X	NA	5	Oosterhoorn and Kappelle 2000.
Costa Rica	Las Cruces, Coto Brus	Subtropical wet forest	NA	NA	X	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1	Peterson and Haines 2000.
Costa Rica	Cordillera Tilaran Monteverde, Puntarenas	Lower Montane wet forest	NA	NA	X	NA	X	NA	NA	NA	X	X	NA	NA	X	5	Piper 2006.
Costa Rica	Las Cruces, Coto Brus	Subtropical wet forest	NA	NA	X	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1	Schlaepfer and Gavin 2001.
Costa Rica	Cordillera Tilaran Monteverde, Puntarenas	Lower Montane wet forest	NA	NA	X	NA	NA	NA	NA	NA	X	X	NA	NA	NA	3	Sillett et al. 1995
Costa Rica	Finca la Suerte, 13 km northwest of the town of Cariari.	Tropical wet forest	NA	NA	X	NA	NA	NA	NA	NA	X	NA	NA	NA	NA	2	Slocum 2000.
Costa Rica	Finca la Suerte, 13 km northwest of the town of Cariari.	Tropical wet forest	NA	X	X	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2	Slocum and Horvitz 2000.

Appendix 3 Continued. Summary of the land uses in pastoral landscapes of Central America in which tree cover has been characterized.

Country	Area	Holdridge Life zone	Pasture (tree cover not indicated)	Pasture without trees	Pasture with trees	Intensive SPS	Live fences	Charrals	Forest plantations	Riparian forest	Secondary forest	Primary forest	Orchard	Annual crops	Perennial crops	Total	Reference
Costa Rica	La Fortuna, San Carlos.	Premontane wet forest	NA	NA	X	X	X	NA	NA	NA	NA	NA	NA	NA	NA	3	Souza de Abreu et al. 2000.
Costa Rica	NP Palo Verde and BR Lomas Barbudal, Guanacaste	Tropical Dry Forests	NA	NA	X	NA	NA	NA	NA	NA	X	NA	NA	NA	NA	2	Stern et al. 2002.
Costa Rica	Rio Frio	Tropical wet forest	X	X	NA	NA	X	X	X	X	X	X	X	NA	NA	9	Villacis et al. 2003.
Costa Rica	Cañas	Tropical Dry Forests	NA	NA	X	NA	X	NA	NA	NA	NA	NA	NA	X	X	4	Villanueva et al. 2003
Costa Rica	San Luis Valley, Guanacaste.	Tropical Dry Forests	NA	NA	X	NA	NA	NA	NA	NA	X	NA	NA	NA	NA	2	Wijdeven and Kuzee 2000.
Guatemala	Reserva Biosfera Maya, Peten	Subtropical wet forest	NA	NA	X	NA	NA	NA	NA	NA	X	NA	NA	NA	NA	2	Hernández and Benavides 1995.
Honduras	Pico Bonito National Park, Honduras	Subtropical wet forest	X	NA	NA	NA	NA	NA	NA	NA	X	NA	NA	NA	NA	2	Zahawi and Augspurger 2006.
Honduras	Pico Bonito National Park, Honduras	Subtropical wet forest	NA	NA	X	NA	X	NA	NA	NA	NA	NA	NA	NA	NA	2	Zahawi 2005.
Mexico	Chajul Biological Station., Montes Azules Biosphere Reserve (MABR), Chiapas.	Tropical Dry Forests	NA	NA	X	NA	NA	NA	NA	NA	X	X	NA	NA	NA	3	Benitez-Malvido 2006.
Mexico	Los Tuxtlas, Veracruz,	Tropical wet forest	X	NA	NA	NA	X	NA	NA	NA	X	X	NA	NA	X	5	Estrada et al. 1994.
Mexico	Los Tuxtlas, Veracruz,	Tropical wet forest	X	NA	NA	NA	X	NA	NA	NA	NA	X	X	NA	X	5	Estrada et al. 1998.

Appendix 3 Continued. Summary of the land uses in pastoral landscapes of Central America in which tree cover has been characterized.

Country	Area	Holdridge Life zone	Pasture (tree cover not indicated)	Pasture without trees	Pasture with trees	Intensive SPS	Live fences	Charrals	Forest plantations	Riparian forest	Secondary forest	Primary forest	Orchard	Annual crops	Perennial crops	Total	Reference
Mexico	Los Tuxtlas, Veracruz,	Tropical wet forest	NA	NA	NA	NA	X	NA	NA	X	X	NA	NA	NA	NA	3	Estrada et al. 2000.
Mexico	San Andrés Tlalnelhuayocan, Veracruz.	Lower Montane wet forest	NA	NA	X	NA	NA	NA	NA	NA	NA	X	NA	NA	NA	2	Flores-Palacios and García-Franco 2004.
Mexico	Los Tuxtlas, Veracruz,	Tropical wet forest	NA	X	X	NA	X	NA	NA	X	NA	X	NA	NA	NA	5	Galindo Gonzalez et al. 2000.
Costa Rica	Cañas	Tropical Dry Forests	NA	NA	X	NA	X	NA	NA	NA	NA	NA	NA	X	X	4	Villanueva et al. 2003
Costa Rica	San Luis Valley, Guanacaste.	Tropical Dry Forests	NA	NA	X	NA	NA	NA	NA	NA	X	NA	NA	NA	NA	2	Wijdeven and Kuzee 2000.
Guatemala	Reserva Biosfera Maya, Peten	Subtropical wet forest	NA	NA	X	NA	NA	NA	NA	NA	X	NA	NA	NA	NA	2	Hernández and Benavides 1995.
Honduras	Pico Bonito National Park, Honduras	Subtropical wet forest	X	NA	NA	NA	NA	NA	NA	NA	X	NA	NA	NA	NA	2	Zahawi and Augspurger 2006.
Honduras	Pico Bonito National Park, Honduras	Subtropical wet forest	NA	NA	X	NA	X	NA	NA	NA	NA	NA	NA	NA	NA	2	Zahawi 2005.
Mexico	Chajul Biological Station., Montes Azules Biosphere Reserve (MABR), Chiapas.	Tropical Dry Forests	NA	NA	X	NA	NA	NA	NA	NA	X	X	NA	NA	NA	3	Benitez-Malvido 2006.
Mexico	Los Tuxtlas, Veracruz,	Tropical wet forest	X	NA	NA	NA	X	NA	NA	NA	X	X	NA	NA	X	5	Estrada et al. 1994.
Mexico	Los Tuxtlas, Veracruz,	Tropical wet forest	X	NA	NA	NA	X	NA	NA	NA	NA	X	X	NA	X	5	Estrada et al. 1998.
Mexico	Los Tuxtlas, Veracruz,	Tropical wet forest	NA	NA	NA	NA	X	NA	NA	X	X	NA	NA	NA	NA	3	Estrada et al. 2000.

Appendix 3 Continued. Summary of the land uses in pastoral landscapes of Central America in which tree cover has been characterized.

Country	Area	Holdridge Life zone	Pasture (tree cover not indicated)	Pasture without trees	Pasture with trees	Intensive SPS	Live fences	Charrals	Forest plantations	Riparian forest	Secondary forest	Primary forest	Orchard	Annual crops	Perennial crops	Total	Reference
Mexico	San Andrés Tlalnelhuayocan, Veracruz.	Lower Montane wet forest	NA	NA	X	NA	NA	NA	NA	NA	NA	X	NA	NA	NA	2	Flores-Palacios and García-Franco 2004.
Mexico	Los Tuxtlas, Veracruz,	Tropical wet forest	NA	X	X	NA	X	NA	NA	X	NA	X	NA	NA	NA	5	Galindo Gonzalez et al. 2000.
Mexico	Ocosingo Valley, Chiapas	Tropical wet forest	NA	X	NA	X	NA	NA	X	NA	X	NA	NA	NA	X	5	Greenberg et al. 1997.
Mexico	Los Tuxtlas, Veracruz,	Tropical wet forest	NA	NA	X	NA	NA	NA	NA	NA	NA	X	NA	NA	NA	2	Guevara and Laborde 1993.
Mexico	Los Tuxtlas, Veracruz,	Tropical wet forest	NA	X	X	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2	Guevara et al. 1992.
Mexico	Los Tuxtlas, Veracruz,	Tropical wet forest	X	NA	X	X	NA	NA	NA	NA	X	X	NA	NA	NA	5	Guevara et al. 1994.
Mexico	Los Tuxtlas, Veracruz,	Tropical wet forest	X	NA	X	NA	NA	NA	NA	X	NA	X	NA	X	X	6	Guevara et al. 1998.
Mexico	Los Tuxtlas, Veracruz,	Tropical wet forest	NA	NA	X	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1	Guevara et al. 2004.
Mexico	Los Tuxtlas, Veracruz,	Tropical wet forest	NA	NA	X	NA	X	NA	NA	NA	NA	NA	NA	NA	NA	2	Guevara et al. 2005a.
Mexico	Los Tuxtlas, Veracruz,	Tropical wet forest	X	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	X	NA	2	Guevara et al. 2005b.
Mexico	Los Tuxtlas, Veracruz,	Tropical wet forest	NA	X	NA	NA	NA	NA	NA	NA	NA	X	NA	NA	NA	2	HietzSeifert et al. 1996.
Mexico	Los Tuxtlas, Veracruz,	Tropical wet forest	X	NA	NA	NA	NA	NA	NA	NA	NA	X	NA	NA	NA	2	Hughes et al. 2000.
Mexico	Los Tuxtlas, Veracruz,	Tropical wet forest	NA	NA	X	NA	NA	X	NA	NA	X	NA	NA	NA	NA	3	Martínez-G et al. 2005.
Mexico	Los Tuxtlas, Veracruz,	Tropical wet forest	X	NA	NA	NA	NA	NA	NA	X	NA	NA	NA	NA	NA	2	Martinez-Garza and González-Montagut 1999.

Appendix 3 Continued. Summary of the land uses in pastoral landscapes of Central America in which tree cover has been characterized.

Country	Area	Holdridge Life zone	Pasture (tree cover not indicated)	Pasture without trees	Pasture with trees	Intensive SPS	Live fences	Charrals	Forest plantations	Riparian forest	Secondary forest	Primary forest	Orchard	Annual crops	Perennial crops	Total	Reference
Mexico	Ejido San Mateo near Chamela, Jalisco.	Tropical Dry Forests	X	NA	NA	NA	NA	NA	NA	NA	X	NA	NA	X	NA	3	Miller 1999
Mexico	Center for Technical Development TANTAKIN, Yucatan.	Tropical Dry Forests	X	NA	NA	NA	NA	NA	NA	NA	X	NA	NA	NA	NA	2	Montiel et al. 2006.
Mexico	Centro de investigaciones costeras La Mancha (CICOLMA), Veracruz	Subtropical wet forest	NA	NA	X	NA	NA	X	NA	NA	X	NA	NA	NA	NA	3	Ortiz-Pulido et al. 2000.
Mexico	Pacific Coastal Plain of Chiapas.	Tropical Dry Forests	NA	NA	X	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1	Otero-Arnaiz et al. 1999.
Mexico	La Antigua River basin, Xalapa - Veracruz.	Tropical wet forest	X	NA	NA	NA	NA	NA	NA	NA	NA	X	NA	NA	X	3	Pineda and Halffter 2004.
Mexico	San Fernando, Chiapas.	Tropical wet forest	X	NA	X	NA	X	NA	NA	X	X	NA	NA	NA	X	6	Pinkus-Rendón et al. 2006.
Mexico	Centro de investigaciones costeras La Mancha (CICOLMA), Veracruz	Subtropical wet forest	X	NA	X	X	NA	X	NA	NA	NA	NA	NA	NA	NA	4	Travieso-B et al. 2005.
Mexico	Los Tuxtlas, Veracruz,	Tropical wet forest	X	NA	X	NA	NA	NA	NA	X	X	NA	NA	NA	NA	4	Williams-Linera et al. 1998.
Nicaragua	Protected area Miraflor-Moropotente, Estelí,	Subtropical wet forest	NA	X	NA	NA	NA	X	NA	NA	X	NA	NA	NA	NA	3	Casasola et al. 2001.
Nicaragua	Rivas, Belen	Tropical Dry Forests	NA	NA	X	NA	X	X	NA	NA	NA	NA	X	X	NA	5	Gómez et al. 2004.
Nicaragua	Matiguas, Matagalpa.	Subtropical wet forest	NA	NA	X	NA	X	X	NA	X	X	NA	NA	NA	NA	5	Harvey et al. 2005
Nicaragua	Rivas, Belen	Tropical Dry Forests	NA	NA	X	NA	X	X	NA	X	X	NA	NA	NA	NA	5	Harvey et al. 2005

Appendix 3 Continued. Summary of the land uses in pastoral landscapes of Central America in which tree cover has been characterized.

Country	Area	Holdridge Life zone	Pasture (tree cover not indicated)	Pasture without trees	Pasture with trees	Intensive SPS	Live fences	Charrals	Forest plantations	Riparian forest	Secondary forest	Primary forest	Orchard	Annual crops	Perennial crops	Total	Reference
Nicaragua	Rivas, Belen	Tropical Dry Forests	NA	NA	X	NA	X	X	NA	X	X	NA	NA	NA	NA	5	Harvey et al. 2006
Nicaragua	Rivas, Belen	Tropical Dry Forests	NA	NA	X	NA	X	X	NA	NA	NA	NA	X	NA	X	5	Joya et al. 2004
Nicaragua	Rivas, Belen	Tropical Dry Forests	NA	NA	X	NA	X	NA	NA	NA	NA	NA	NA	NA	NA	2	López et al. 2004
Nicaragua	Boaco (Mpios Camoapa, San Lorenzo, teustepe y Boaco)	Tropical wet forest	X	NA	X	NA	NA	NA	X	NA	NA	X	NA	NA	NA	4	Medina et al. 2001.
Nicaragua	Rivas, Belen	Tropical Dry Forests	NA	NA	X	NA	X	X	NA	X	X	NA	NA	NA	NA	5	Sánchez Merlo et al. 2004.
Nicaragua	Rivas, Belen	Tropical Dry Forests	NA	NA	X	NA	X	X	NA	X	X	NA	NA	NA	NA	5	Sánchez Merlo et al. 2005a.
Nicaragua	Matiguas, Matagalpa.	Subtropical wet forest	NA	X	NA	NA	X	X	NA	X	X	NA	NA	NA	NA	5	Sánchez Merlo et al. 2005b.
Nicaragua	Boaco (Mpios Camoapa, San Lorenzo, teustepe y Boaco)	Tropical wet forest	NA	NA	X	X	NA	NA	X	NA	X	NA	NA	NA	NA	4	Zamora et al. 2001.
Panama	Chiriqui, Bugaba, Santa Marta (30 km2), Santo Domingo (51 km2) y Sortová (35 km2)	Tropical wet forest	NA	NA	X	NA	X	X	NA	NA	NA	X	NA	NA	NA	4	Cerrud, R et al. 2004.

Appendix 3 Continued. Summary of the land uses in pastoral landscapes of Central America in which tree cover has been characterized.

Country	Area	Holdridge Life zone	Pasture (tree cover not indicated)	Pasture without trees	Pasture with trees	Intensive SPS	Live fences	Charrals	Forest plantations	Riparian forest	Secondary forest	Primary forest	Orchard	Annual crops	Perennial crops	Total	Reference
Panama	La Pavas, Canal de Panama.	Premontane wet forest	X	NA	NA	NA	NA	NA	NA	NA	X	NA	NA	X	NA	3	Hooper et al. 2004.
Panama	La Pavas, Canal de Panama.	Premontane wet forest	NA	X	NA	NA	NA	NA	NA	NA	X	NA	NA	X	NA	3	Hooper et al. 2005.
Total			**35**	**11**	**60**	**10**	**32**	**18**	**9**	**19**	**46**	**27**	**6**	**12**	**16**		

Appendix 4. Sampling scale and number of time of samples in studies of tree cover within pastoral landscapes in Mesoamerica.

Area	Country	Holdrige Life zone	Scale of measurement			No. time of sampled		Reference
			Landscape	Farm	Plot	Single season	Monitoring	
Caribbean Microregion, Litoral, Sabanas, Golfo de Morrosquillo y Valle del Zinu.	Colombia	Tropical Dry Forests	NA	X	NA	NA	X	Cajas-Giron and Sinclair 2001.
Bellavista, El Dovio, Valle del Cauca	Colombia	Premontane wet forest	NA	NA	X	X	NA	Esquivel-Sheik and Calle Diaz 2002.
Filandia, Quindio and Pereira, Risaralda	Colombia	Lower Montane wet forest	X	NA	NA	NA	X	Mendoza et al. 2005
Aranzazu, Caldas	Colombia	Lower Montane wet forest	NA	NA	X	NA	X	Otero et al. 2006.
Ranch Farm (CRQ), Pijao, quindío	Colombia	Montane pluvial forest	NA	NA	X	NA	X	Posada et al. 2000
Florencia, Caquetá.	Colombia	Tropical wet forest	NA	NA	X	X	NA	Ramírez 2002.
Quepos, Puntarenas	Costa Rica	Tropical Dry Forests	NA	NA	X	NA	X	Berninger and Salas 2003.
Esparza	Costa Rica	Subtropical wet forest	NA	NA	X	X	NA	Camargo et al. 2000.
Guapiles	Costa Rica	Tropical wet forest	NA	NA	X	X	NA	Camargo et al. 2000.
Cañas	Costa Rica	Tropical Dry Forests	NA	NA	X	X	NA	Cárdenas et al. 2003.
Las Cruces, Coto Brus	Costa Rica	Subtropical wet forest	NA	NA	X	NA	X	Carpenter et al. 2004a.
Las Cruces, Coto Brus	Costa Rica	Subtropical wet forest	NA	NA	X	NA	X	Carpenter et al. 2004b.
Rio Frio	Costa Rica	Tropical wet forest	X	NA	NA	X	NA	Chacon-L and Harvey 2005
Cañas	Costa Rica	Tropical Dry Forests	NA	X	NA	NA	X	Esquivel et al. 2003.
Cañas	Costa Rica	Tropical Dry Forests	NA	NA	X	X	NA	Ghazoul and McLeish 2001.
Cordillera Tilaran Monteverde, Puntarenas	Costa Rica	Lower Montane wet forest	X	NA	NA	NA	X	Harvey 2000a.
Cordillera Tilaran Monteverde, Puntarenas	Costa Rica	Lower Montane wet forest	X	NA	NA	NA	X	Harvey 2000b.
Cordillera Tilaran Monteverde, Puntarenas	Costa Rica	Lower Montane wet forest	NA	NA	X	X	NA	Harvey and Haber 1999.

Appendix 4 Continued. Sampling scale and number of time of samples in studies of tree cover within pastoral landscapes in Mesoamerica.

Area	Country	Holdrige Life zone	Scale of measurement			No. time of sampled		Reference
			Landscape	Farm	Plot	Single season	Monitoring	
Cordillera Tilaran Monteverde, Puntarenas	Costa Rica	Lower Montane wet forest	NA	NA	X	X	NA	Harvey et al. 1999.
Cañas	Costa Rica	Tropical Dry Forests	X	NA	NA	NA	X	Harvey et al. 2005.
Rio Frio	Costa Rica	Tropical wet forest	X	NA	NA	NA	X	Harvey et al. 2005.
Puerto Jimenez, Peninzula de Osa.	Costa Rica	Tropical wet forest	NA	NA	X	NA	X	Healey and Gara 2003.
Las Alturas, Coto Brus.	Costa Rica	Lower Montane wet forest	NA	NA	X	NA	X	Holl 1998.
Las Alturas, Coto Brus.	Costa Rica	Lower Montane wet forest	NA	NA	X	X	NA	Holl and Quiros-Nietzen 1999.
Rio Frio	Costa Rica	Tropical wet forest	NA	NA	X	X	NA	Lang et al. 2003
Las Alturas, Coto Brus.	Costa Rica	Lower Montane wet forest	NA	NA	X	NA	X	Lindell et al. 2004
Las Cruces, Coto Brus	Costa Rica	Subtropical wet forest	X	NA	NA	X	NA	Luck and Daily 2003.
Puerto _Jimenez y la Palma , Peninzula de Osa.	Costa Rica	Tropical wet forest	NA	NA	X	NA	X	Mayfield and Daily 2005.
Puerto _Jimenez y la Palma , Peninzula de Osa.	Costa Rica	Tropical wet forest	NA	NA	X	X	NA	Mayfield et al. 2005.
Puerto _Jimenez y la Palma , Peninzula de Osa.	Costa Rica	Tropical wet forest	NA	NA	X	NA	X	Mayfield et al. 2006.
Guaira Annex of La Selva Biological Station, Sarapiquí.	Costa Rica	Tropical wet forest	NA	NA	X	NA	X	Montagnini et al. 2003.
La Culebra, San Carlos.	Costa Rica	Tropical wet forest	NA	NA	X	NA	X	Moulaert et al. 2002.
Cañas	Costa Rica	Tropical Dry Forests	NA	X	NA	X	NA	Muñoz et al. 2003
Rio Frio	Costa Rica	Tropical wet forest	NA	X	NA	X	NA	Muñoz et al. 2004
Volvan BARU, San Vito de Coto Brus,	Costa Rica	Premontane wet forest	NA	NA	X	NA	X	Nichols et al. 2001.
Los Santos and Río Macho Forest Reserves, Cordillera de Talamanca	Costa Rica	Montane pluvial forest	NA	NA	X	NA	X	Oosterhoorn and Kappelle 2000.
Las Cruces, Coto Brus	Costa Rica	Subtropical wet forest	NA	NA	X	NA	X	Peterson and Haines 2000.

Appendix 4 Continued. Sampling scale and number of time of samples in studies of tree cover within pastoral landscapes in Mesoamerica.

Area	Country	Holdrige Life zone	Scale of measurement			No. time of sampled		Reference
			Landscape	Farm	Plot	Single season	Monitoring	
Cordillera Tilaran Monteverde, Puntarenas	Costa Rica	Lower Montane wet forest	NA	NA	X	NA	X	Piper 2006.
Las Cruces, Coto Brus	Costa Rica	Subtropical wet forest	X	NA	NA	X	NA	Schlaepfer and Gavin 2001.
Finca la Suerte, 13 km northwest of the town of Cariari.	Costa Rica	Tropical wet forest	NA	NA	X	X	NA	Slocum 2000.
La Fortuna, San Carlos.	Costa Rica	Premontane wet forest	NA	X	NA	NA	X	Souza de Abreu et al. 2000.
NP Palo Verde and BR Lomas Barbudal, Guanacaste	Costa Rica	Tropical Dry Forests	NA	NA	X	X	NA	Stern et al. 2002.
Rio Frio	Costa Rica	Tropical wet forest	NA	X	NA	NA	X	Villacis et al. 2003.
Cañas	Costa Rica	Tropical Dry Forests	NA	X	NA	NA	X	Villanueva et al. 2003.
Reserva Biosfera Maya, Peten	Guatemala	Subtropical wet forest	NA	NA	X	X	NA	Hernández and Benavides 1995.
Pico Bonito National Park, Honduras	Honduras	Subtropical wet forest	NA	NA	X	NA	X	Zahawi 2005
Chajul Biological Station., Montes Azules Biosphere Reserve (MABR), Chiapas.	Mexico	Tropical Dry Forests	NA	NA	X	X	NA	Benitez-Malvido 2006.
Los Tuxtlas, Veracruz,	Mexico	Tropical wet forest	X	NA	NA	NA	X	Estrada et al. 1994.
Los Tuxtlas, Veracruz,	Mexico	Tropical wet forest	X	NA	NA	NA	X	Estrada et al. 1998.
Los Tuxtlas, Veracruz,	Mexico	Tropical wet forest	X	NA	NA	NA	X	Estrada et al. 2000.
San Andrés Tlalnelhuayocan, Veracruz.	Mexico	Lower Montane wet forest	NA	NA	X	X	NA	Flores-Palacios and García-Franco 2004.
Ocosingo Valley, Chiapas	Mexico	Tropical wet forest	NA	NA	X	NA	X	Greenberg et al. 1997.
Los Tuxtlas, Veracruz,	Mexico	Tropical wet forest	NA	NA	X	X	NA	Guevara et al. 1992.
Los Tuxtlas, Veracruz,	Mexico	Tropical wet forest	NA	X	NA	X	NA	Guevara et al. 1994.
Los Tuxtlas, Veracruz,	Mexico	Tropical wet forest	NA	NA	X	NA	X	Guevara et al. 1998.
Los Tuxtlas, Veracruz,	Mexico	Tropical wet forest	NA	NA	X	NA	X	Guevara et al. 2004.

Appendix 4 Continued. Sampling scale and number of time of samples in studies of tree cover within pastoral landscapes in Mesoamerica.

Area	Country	Holdrige Life zone	Scale of measurement			No. time of sampled		Reference
			Landscape	Farm	Plot	Single season	Monitoring	
Los Tuxtlas, Veracruz,	Mexico	Tropical wet forest	NA	NA	X	NA	X	Guevara et al. 2005a.
Los Tuxtlas, Veracruz,	Mexico	Tropical wet forest	X	NA	NA	NA	X	Hughes et al. 2000.
Los Tuxtlas, Veracruz,	Mexico	Tropical wet forest	NA	NA	X	NA	X	Martínez-G et al. 2005.
Los Tuxtlas, Veracruz,	Mexico	Tropical wet forest	NA	NA	X	X	NA	Martinez-Garza and González-Montagut 1999.
Ejido San Mateo near Chamela, Jalisco.	Mexico	Tropical Dry Forests	NA	NA	X	NA	X	Miller 1999
Center for Technical Development TANTAKIN, Yucatan.	Mexico	Tropical Dry Forests	X	NA	NA	NA	X	Montiel et al. 2006.
Centro de investigaciones costeras La Mancha (CICOLMA), Veracruz	Mexico	Subtropical wet forest	X	NA	NA	NA	X	Ortiz-Pulido et al. 2000.
Pacific Coastal Plain of Chiapas.	Mexico	Tropical Dry Forests	NA	NA	X	X	NA	Otero-Arnaiz et al. 1999.
La Antigua River basin, Xalapa - Veracruz.	Mexico	Tropical wet forest	X	NA	NA	NA	X	Pineda and Halffter 2004.
San Fernando, Chiapas.	Mexico	Tropical wet forest	NA	NA	X	X	NA	Pinkus-Rendón et al. 2006.
Centro de investigaciones costeras La Mancha (CICOLMA), Veracruz	Mexico	Subtropical wet forest	NA	NA	X	X	NA	Travieso-B et al. 2005.
Los Tuxtlas, Veracruz,	Mexico	Tropical wet forest	X	NA	NA	X	NA	Williams-Linera et al. 1998.
Protected area Miraflor-Moropotente, Estelí,	Nicaragua	Subtropical wet forest	NA	X	NA	X	NA	Casasola et al. 2001.
Rivas, Belen	Nicaragua	Tropical Dry Forests	NA	X	NA	X	NA	Gómez et al. 2004.
Matiguas, Matagalpa.	Nicaragua	Subtropical wet forest	X	NA	NA	NA	X	Harvey et al. 2005.
Rivas, Belen	Nicaragua	Tropical Dry Forests	X	NA	NA	NA	X	Harvey et al. 2005.

Appendix 4 Continued. Sampling scale and number of time of samples in studies of tree cover within pastoral landscapes in Mesoamerica.

Area	Country	Holdrige Life zone	Scale of measurement			No. time of sampled		Reference
			Landscape	Farm	Plot	Single season	Monitoring	
Rivas, Belen	Nicaragua	Tropical Dry Forests	NA	NA	X	NA	X	Harvey et al. 2006.
Rivas, Belen	Nicaragua	Tropical Dry Forests	NA	X	NA	X	NA	Joya et al. 2004
Rivas, Belen	Nicaragua	Tropical Dry Forests	NA	X	NA	X	NA	López et al. 2004
Boaco (Mpios Camoapa, San Lorenzo, teustepe y Boaco)	Nicaragua	Tropical wet forest	NA	X	NA	X	NA	Medina et al. 2001.
Rivas, Belen	Nicaragua	Tropical Dry Forests	NA	NA	X	NA	X	Sánchez Merlo et al. 2004.
Rivas, Belen	Nicaragua	Tropical Dry Forests	NA	NA	X	NA	X	Sánchez Merlo et al. 2005a.
Matiguas, Matagalpa.	Nicaragua	Subtropical wet forest	NA	NA	X	NA	X	Sánchez Merlo et al. 2005b.
Boaco (Mpios Camoapa, San Lorenzo, teustepe y Boaco)	Nicaragua	Tropical wet forest	NA	X	NA	X	NA	Zamora et al. 2001.
Chiriqui, Bugaba, Santa Marta (30 km2), Santo Domingo (51 km2) y Sortová (35 km2)	Panama	Tropical wet forest	NA	NA	X	X	NA	Cerrud, R et al. 2004.
La Pavas, Canal de Panama.	Panama	Premontane wet forest	NA	NA	X	NA	X	Hooper et al. 2004.
	Total		**18**	**14**	**50**	**35**	**47**	

Appendix 5. Data collected in studies of tree cover within pastoral landscapes in Mesoamerica.

Reference	Data collected										
	Basal Area	density/ abundance	Richnness	Height	DBH	Diversity	% canopy cover	Demography	Phenology	Tree uses	Information on utilitarian use of tree species
Cajas-Giron and Sinclair 2001.	NA	X	X	NA	NA	NA	X	NA	X	X	X
Esquivel-Sheik and Calle Diaz 2002.	NA	X	X	NA	NA	NA	NA	NA	NA	X	NA
Mendoza et al. 2005	NA	X	X	NA	NA	NA	NA	NA	NA	X	X
Otero et al. 2006.	NA	X	X	NA	NA	NA	NA	NA	NA	X	X
Posada et al. 2000	NA	X	X	NA	NA	X	NA	NA	NA	NA	NA
Ramírez 2002.	NA	NA	NA	NA	NA	NA	NA	NA	NA	X	X
Berninger and Salas 2003.	NA	NA	NA	NA	NA	NA	NA	NA	X	X	X
Camargo et al. 2000.	NA	X	NA	NA	NA	NA	NA	X	NA	X	NA
Camargo et al. 2000.	NA	X	NA	NA	NA	NA	NA	X	NA	X	NA
Cárdenas et al. 2003.	NA	NA	X	X	X	NA	NA	NA	NA	NA	NA
Carpenter et al. 2004a.	NA	NA	X	NA	NA	NA	NA	X	NA	NA	NA
Carpenter et al. 2004b.	NA	NA	NA	NA	NA	NA	NA	X	NA	X	X
Chacon-L and Harvey 2005	NA	X	X	NA	X	NA	NA	NA	NA	NA	NA
Esquivel et al. 2003.	NA	X	X	X	X	NA	X	NA	X	X	X
Ghazoul and McLeish 2001.	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Harvey 2000a.	NA	NA	X	NA	NA	NA	NA	NA	NA	NA	X
Harvey 2000b.	NA	X	X	NA	NA	NA	NA	NA	NA	NA	X
Harvey and Haber 1999.	NA	X	X	X	X	NA	NA	NA	NA	X	X
Harvey et al. 1999.	NA	X	X	NA	NA	NA	NA	NA	NA	X	X
Harvey et al. 2005.	NA	X	X	X	X	NA	NA	NA	NA	X	X
Harvey et al. 2005.	NA	X	X	X	X	NA	X	NA	NA	X	X
Healey and Gara 2003.	NA	X	X	NA	NA	NA	NA	NA	NA	X	NA
Holl 1998.	NA	NA	X	NA	NA	NA	NA	NA	NA	NA	NA
Holl and Quiros-Nietzen 1999.	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Lang et al. 2003	NA	X	NA	X	X	NA	NA	NA	NA	NA	NA

Appendix 5 Continued. Data collected in studies of tree cover within pastoral landscapes in Mesoamerica.

Reference	Data collected										
	Basal Area	density/ abundance	Richnness	Height	DBH	Diversity	% canopy cover	Demography	Phenology	Tree uses	Information on utilitarian use of tree species
Lindell et al. 2004	NA	X	X	X	X	NA	X	NA	NA	NA	X
Luck and Daily 2003.	NA	NA	NA	NA	NA	NA	NA	X	NA	X	X
Mayfield and Daily 2005.	NA	X	X	NA	NA	X	NA	X	X	X	NA
Mayfield et al. 2005.	NA	NA	X	NA	NA	NA	NA	NA	NA	NA	NA
Mayfield et al. 2006.	NA	NA	NA	NA	NA	NA	NA	X	X	NA	X
Montagnini et al. 2003.	NA	NA	NA	NA	NA	NA	NA	NA	NA	X	X
Moulaert et al. 2002.	NA	NA	NA	NA	NA	NA	NA	X	NA	X	X
Muñoz et al. 2003	NA	NA	X	NA	NA	NA	NA	NA	NA	X	X
Muñoz et al. 2004	NA	NA	X	NA	NA	NA	NA	NA	NA	X	X
Nichols et al. 2001.	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	X
Oosterhoorn and Kappelle 2000.	X	X	X	NA	NA	X	X	NA	NA	NA	NA
Peterson and Haines 2000.	NA	NA	X	NA	NA	NA	NA	NA	NA	NA	NA
Piper 2006.	NA	X	X	NA	X	NA	NA	NA	NA	X	NA
Schlaepfer and Gavin 2001.	NA	X	NA	NA	X	NA	X	NA	NA	NA	NA
Slocum 2000.	NA	X	X	NA	NA	NA	NA	NA	NA	X	NA
Souza de Abreu et al. 2000.	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Stern et al. 2002.	NA	X	X	NA	NA	X	NA	NA	NA	NA	NA
Villacis et al. 2003.	NA	X	X	X	X	X	X	NA	NA	NA	X
Villanueva et al. 2003.	NA	X	X	NA	NA	X	X	NA	X	X	X
Hernández and Benavides 1995.	NA	NA	X	NA	NA	NA	NA	NA	NA	X	X
Zahawi 2005	NA	NA	NA	NA	NA	NA	X	NA	NA	X	X
Benitez-Malvido 2006.	NA	X	X	NA	NA	NA	NA	NA	NA	X	NA
Estrada et al. 1994.	NA	NA	X	NA	NA	NA	NA	NA	NA	X	NA
Estrada et al. 1998.	NA	NA	NA	NA	NA	X	NA	NA	NA	NA	NA
Estrada et al. 2000.	NA	NA	X	X	X	NA	NA	NA	NA	NA	NA

Appendix 5 Continued. Data collected in studies of tree cover within pastoral landscapes in Mesoamerica.

Reference	Data collected									
	Basal Area	density/ abundance	Richnness	Height	DBH	Diversity	% canopy cover	Demography	Phenology	Tree uses	Information on utilitarian use of tree species
Flores-Palacios and García-Franco 2004.	NA	NA	X	X	X	NA	NA	NA	NA	X	NA
Greenberg et al. 1997.	NA	X	NA	NA	NA	NA	NA	NA	NA	X	NA
Guevara et al. 1992.	NA	NA	X	NA	NA	NA	X	NA	NA	X	NA
Guevara et al. 1994.	NA	X	X	NA	NA	NA	NA	X	NA	X	NA
Guevara et al. 1998.	NA	X	X	X	NA	NA	X	X	NA	X	NA
Guevara et al. 2004.	NA	X	X	NA	NA	NA	X	NA	NA	X	NA
Guevara et al. 2005a.	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Hughes et al. 2000.	NA	NA	NA	NA	NA	NA	NA	NA	NA	X	X
Martínez-G et al. 2005.	NA	NA	X	X	NA	NA	NA	NA	NA	NA	NA
Martinez-Garza and González-Montagut 1999.	NA	X	X	X	X	NA	NA	NA	NA	NA	NA
Miller 1999	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Montiel et al. 2006.	NA	X	NA	NA	NA	NA	NA	NA	NA	X	NA
Ortiz-Pulido et al. 2000.	NA	NA	X	NA	NA	NA	NA	NA	NA	NA	NA
Otero-Arnaiz et al. 1999.	NA	X	X	NA	NA	NA	NA	NA	NA	X	NA
Pineda and Halffter 2004.	NA	NA	NA	NA	NA	NA	X	NA	NA	NA	NA
Pinkus-Rendón et al. 2006.	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Travieso-B et al. 2005.	NA	NA	X	NA	NA	NA	NA	NA	NA	NA	NA
Williams-Linera et al. 1998.	NA	NA	X	NA	NA	NA	NA	X	X	X	NA
Casasola et al. 2001.	NA	X	X	NA	NA	NA	NA	NA	NA	X	X
Gómez et al. 2004.	NA	NA	NA	NA	NA	NA	X	X	NA	X	NA
Harvey et al. 2005.	NA	X	X	X	X	NA	NA	NA	NA	X	X
Harvey et al. 2005.	NA	X	X	X	X	NA	NA	NA	NA	X	X
Harvey et al. 2006.	NA	X	X	X	X	NA	X	X	NA	NA	X

Appendix 5 Continued. Data collected in studies of tree cover within pastoral landscapes in Mesoamerica.

Reference	Data collected										
	Basal Area	density/ abundance	Richnness	Height	DBH	Diversity	% canopy cover	Demography	Phenology	Tree uses	Information on utilitarian use of tree species
Joya et al. 2004	NA	NA	X	NA	NA	NA	NA	NA	NA	X	X
López et al. 2004	NA	X	X	NA	NA	NA	X	X	NA	X	X
Medina et al. 2001.	NA	X	X	X	X	NA	NA	NA	NA	NA	X
Sánchez Merlo et al. 2004.	NA	NA	X	NA	NA	NA	NA	NA	NA	X	X
Sánchez Merlo et al. 2005a.	NA	X	X	X	X	X	NA	NA	NA	X	X
Sánchez Merlo et al. 2005b.	X	X	X	X	X	NA	X	X	NA	X	NA
Zamora et al. 2001.	NA	X	X	X	X	NA	NA	NA	NA	NA	X
Cerrud, R et al. 2004.	NA	X	X	NA	NA	NA	NA	NA	NA	X	X
Hooper et al. 2004.	NA	X	X	NA	NA	NA	NA	NA	NA	NA	NA
Total	**2**	**44**	**57**	**20**	**21**	**8**	**17**	**15**	**7**	**48**	**37**

Appendix 6. Summary of studies that looked at tree regeneration within pastures in Mesoamerica. Pasture type refers to actively grazed pastures (A) or abandoned or fenced pastures (NA).

Area	Country	Holdridge_Life_zone	Pasture type	Development stage				Reference
				Sapling	Seedling	Seed rain	Seed bank	
Bellavista, El Dovio, Valle del Cauca	Colombia	Premontane wet forest	A	X	NA	NA	NA	Esquivel-Sheik and Calle Diaz 2002.
Western slope of the Volcán Barba	Costa Rica	Lower Montane wet forest	A	NA	NA	X	NA	Barrantes and Pereira 2002.
Esparza	Costa Rica	Subtropical wet forest	A	X	NA	NA	NA	Camargo et al. 2000.
Guapiles	Costa Rica	Tropical wet forest	A	X	NA	NA	NA	Camargo et al. 2000.
Las Cruces, Coto Brus	Costa Rica	Subtropical wet forest	A	X	X	NA	NA	Carpenter et al. 2004a.
Las Cruces, Coto Brus	Costa Rica	Subtropical wet forest	A	X	NA	NA	NA	Carpenter et al. 2004b.
Cordillera Tilaran Monteverde, Puntarenas	Costa Rica	Lower Montane wet forest	A	NA	X	NA	NA	Harvey 2000a.
Cordillera Tilaran Monteverde, Puntarenas	Costa Rica	Lower Montane wet forest	A	NA	X	X	NA	Harvey 2000b.
Las Alturas, Coto Brus.	Costa Rica	Lower Montane wet forest	NA	NA	NA	X	NA	Holl 1998.
Las Alturas, Coto Brus.	Costa Rica	Lower Montane wet forest	NA	X	X	X	NA	Holl 2002.
Las Alturas, Coto Brus.	Costa Rica	Lower Montane wet forest	NA	X	X	X	NA	Holl and Lulow 1997.
Las Alturas, Coto Brus.	Costa Rica	Lower Montane wet forest	NA	NA	X	NA	NA	Holl and Quiros-Nietzen 1999.
Las Alturas, Coto Brus.	Costa Rica	Lower Montane wet forest	NA	X	X	X	NA	Holl et al 2000.
Las Cruces, Coto Brus	Costa Rica	Subtropical wet forest	NA	NA	X	NA	X	Jones et al. 2003
Puerto _Jimenez y la Palma , Peninzula de Osa.	Costa Rica	Tropical wet forest	A	X	NA	NA	X	Mayfield et al. 2006.
Guaira Annex of La Selva Biological Station, Sarapiquí.	Costa Rica	Tropical wet forest	NA	X	X	NA	NA	Montagnini et al. 2003.
La Culebra, San Carlos.	Costa Rica	Tropical wet forest	A	X	X	NA	NA	Mayfield et al. 2006.

Appendix 6 Continued. Summary of studies that looked at tree regeneration within pastures in Mesoamerica. Pasture type refers to actively grazed pastures (A) or abandoned or fenced pastures (NA).

Area	Country	Holdridge_Life_zone	Pasture type	Development stage				Reference
				Sapling	Seedling	Seed rain	Seed bank	
Los Santos and Río Macho Forest Reserves, Cordillera de Talamanca	Costa Rica	Montane pluvial forest	NA	X	X	NA	NA	Oosterhoorn and Kappelle 2000.
Las Cruces, Coto Brus	Costa Rica	Subtropical wet forest	NA	X	NA	NA	NA	Peterson and Haines 2000.
Cordillera Tilaran Monteverde, Puntarenas	Costa Rica	Lower Montane wet forest	NA	X	X	NA	NA	Piper 2006.
Finca la Suerte, 13 km northwest of the town of Cariari.	Costa Rica	Tropical wet forest	NA	NA	X	NA	NA	Slocum 2000.
Finca la Suerte, 13 km northwest of the town of Cariari.	Costa Rica	Tropical wet forest	NA	NA	NA	X	NA	Slocum and Horvitz 2000.
NP Palo Verde and BR Lomas Barbudal, Guanacaste	Costa Rica	Tropical Dry Forests	A	X	NA	NA	NA	Stern et al. 2002.
San Luis Valley, Guanacaste.	Costa Rica	Tropical Dry Forests	NA	NA	NA	X	X	Wijdeven and Kuzee 2000.
Pico Bonito National Park, Honduras	Honduras	Subtropical wet forest	NA	NA	X	X	NA	Zahawi and Augspurger 2006.
Pico Bonito National Park, Honduras	Honduras	Subtropical wet forest	NA	X	NA	NA	NA	Zahawi 2005
Chajul Biological Station., Montes Azules Biosphere Reserve (MABR), Chiapas.	Mexico	Tropical Dry Forests	NA	X	NA	NA	NA	Benitez-Malvido 2006.
Los Tuxtlas, Veracruz,	Mexico	Tropical wet forest	NA	NA	NA	X	NA	Galindo Gonzalez et al. 2000.
Los Tuxtlas, Veracruz,	Mexico	Tropical wet forest	NA	NA	X	NA	X	Guevara and Laborde 1993.
Los Tuxtlas, Veracruz,	Mexico	Tropical wet forest	NA	X	NA	NA	NA	Guevara et al. 1994.
Los Tuxtlas, Veracruz,	Mexico	Tropical wet forest	NA	NA	X	X	X	Guevara et al. 2004.

Appendix 6 Continued. Summary of studies that looked at tree regeneration within pastures in Mesoamerica. Pasture type refers to actively grazed pastures (A) or abandoned or fenced pastures (NA).

Area	Country	Holdridge_Life_zone	Pasture type	Development stage				Reference
				Sapling	Seedling	Seed rain	Seed bank	
Los Tuxtlas, Veracruz,	Mexico	Tropical wet forest	NA	X	X	NA	NA	Guevara et al. 2005a.
Los Tuxtlas, Veracruz,	Mexico	Tropical wet forest	NA	NA	X	NA	X	Guevara et al. 2005b.
Los Tuxtlas, Veracruz,	Mexico	Tropical wet forest	NA	NA	X	NA	NA	Martínez-G et al. 2005.
Los Tuxtlas, Veracruz,	Mexico	Tropical wet forest	NA	NA	NA	X	NA	Martinez-Garza and González-Montagut 1999.
Ejido San Mateo near Chamela, Jalisco.	Mexico	Tropical Dry Forests	NA	NA	X	NA	X	Miller 1999
Centro de investigaciones costeras La Mancha (CICOLMA), Veracruz	Mexico	Subtropical wet forest	NA	NA	NA	X	NA	Ortiz-Pulido et al. 2000.
Pacific Coastal Plain of Chiapas.	Mexico	Tropical Dry Forests	NA	X	X	NA	NA	Otero-Arnaiz et al. 1999.
Chiriqui, Bugaba, Santa Marta (30 km2), Santo Domingo (51 km2) y Sortová (35 km2)	Panama	Tropical wet forest	NA	X	X	NA	NA	Cerrud, R et al. 2004.
La Pavas, Canal de Panama.	Panama	Premontane wet forest	NA	X	X	NA	NA	Hooper et al. 2004.
La Pavas, Canal de Panama.	Panama	Premontane wet forest	NA	NA	X	NA	X	Hooper et al. 2005.
Total			**11**	22	24	13	8	

Appendix 7. Bibliography of papers on trees and productivity reviewed in Section 3.

Aletor VA and Omodara OA (1994) Studies on some leguminous browse plants, with particular reference to their proximate, mineral and some endogenous anti-nutritional constituents. *Animal Feed and Technology* **46**:343-348.

Andrade H (1999) Dinamica Productiva de Sistemas Silvopastoriles con *Acacia mangium* y *Eucalyptus deglupta* en el tropico humedo. MSc Tesis, Centro Agronomico Tropical de Investigacion y Ensenanza-CATIE, Turrialba, Costa Rica**.**

Argel P and Keller-Grein (1996) Regional experience with Brachiaria: Tropical America Humidid Lowlands. In: JW Miles, BL Bas and Cb do Valle (eds). Brachiaria: Biology, agronomy and Improvement. CIAT, Cali, Colombia. Pp 205-224.

Aquino, D; Hernández, S; Nuncio, MG; Andrade, H. (2004) Response of some tropical grasses in a timber plantation. *In* Mannetje, L; Ramírez, L; Ibrahim M; Sandoval C; Ojeda N; Ku J. eds. The importance of Silvopastoral Systems for Providing Ecosystems Services and Rural livehoods. Mérida, MX. p. 272-276.

Bolivar VDM (1998) Contribución de la *Acacia mangium* al mejoramiento de la calidad forrajera de *Brachiaria humidicola* y la fertilidad de un suelo acido en el trópico húmedo. MSc Tesis, Centro Agronómico Tropical de Investigación y Enseñanza-CATIE, Turrialba, Costa Rica**.**

Bustamante J, Ibrahim M and Beer J (1998) Evaluación agronómica de ocho gramíneas mejoradas en un sistema silvopastoril co poro (*Erythrina poeppigiana*) en el trópico húmedo de Turrialba. *Agroforestería en las Américas* **5** (19):11-16.

Cajas-Girón YS and Sinclair FL (2001) Characterisation of multistrata silvopastoral systems on seasonally dry pasture in the Caribbean region of Colombia. *Agroforestry Systems* **53**:215-225

Cajas-Girón YS (2002) Impacts of tree diversity on the productivity of silvopastoral systems in seasonally dry areas of Colombia. PhD thesis, University of Wales, Bangor. UK. 214 pp.

Cajas-Girón YS, Martinez J, Sanchez C y Panza B (2004) Estrategias de Innovación Tecnológica para mejorar la competitividad y sostenibilidad de los Sistemas de Producción de carne y leche bovina en el Valle del Sinú y Sabanas de Bolívar, Córdoba y Sucre. Informe anual, Conciencias, CORPOICA, Fedegan. 70pp.

Camargo JC, Feijoo A, Zúñiga MC, Cardona H and Gaviria J (2005) Silvopastoral systems with isolated timber trees within pastures in the Coffee region of Colombia. *Livestock Research for Rural Development* 17: (5)

Camero A, Ibrahim M and Kass M (2001) Improving rumen fermentation and milk with legume-tree fodder in the tropics. *Agroforestry Systems* **51**:157-166

Casasola CF (2000) Productividad de los sistemas silvopastoriles tradicionales en Moroponte, Esteli, Nicaragua. MSc Tesis, Centro Agronómico Tropical de Investigación y Enseñanza-CATIE, Turrialba, Costa Rica**.**

CIPAV (2002) Tres especies promisorias: Nacedero *Thrichanthera gigantea*, Boton de Oro *Thitonia diversifolia*, y Bore *Alocasia macrrohiza*. 282 p.

Esquivel H, Ibrahim M, Harvey C, Villanueva C, Benjamin T y Sinclair F (2003) Arboles dispersos en potreros de fincas ganaderas en un sistema seco de Costa Rica. *Agroforesteria en las Americas* **10** (39-40):24-29

Delgado Gomez HJ, Ramirez Aviles L, Ku Vera JC, Velazquez Madrazo PA and Escamilla Bencomo JA (2001) Forage yield root density and soil water relationship of a mixture of *Panicum maximum* and *Leucaena leucocephala* compared to a monoculture of *P. maximum* in Yucatan, Mexico. Curso Virtual de SSP-LEAD-CATIE.

Galindo WF y Giraldo LA (2003) Acacia Negra (*Acacia decurrens*). IN: Manejo Sostenible de los Sistemas Ganaderos Andinos (Ed. Galindo W y Enriquez ML). Cali, Colombia.

Giraldo, LA. (1999a) Potencial del Guácimo (*Guazuma ulmifolia*) en sistemas silvopastoriles. In: Sánchez M.D and Rosales. M (eds.). Agroforesteria para la Producción Animal en América Latina. FAO. Pp 295 - 308.

Giraldo, LA. (1999b) Evaluación del potencial multipropósito en dos especies de acacia para el desarrollo de sistemas silvopastoriles en clima frió. Memorias V ENICIP, Revista Colombiana de Ciencias Pecuarias. Vol. 12, Suplemento, p. 36.

Giraldo LA (2000) Sistemas silvopastoriles, alternativa sostenible para la ganadería en Colombia. Universidad Nacional de Colombia Sede Medellín – PRONATA – CONSILVO. Medellín, Colombia

Gomez M E and Murgueitio E 1991 Efecto de la altura de corte sobre la producción de biomasa de nacedero (*Trichanthera gigantea)*. Livestock Research for Rural Development 3 (3):14- 23.

Harvey CA and Harber WA (1998) Remnant trees and the conservation of biodiversity in Costa Rica pastures. *Agroforestry Systems* **44**: 37-68

Hernandez KJ, Ibrahim M, Detlefsen G, Harvey C, Prins K (2002) Cuantificacion y calificacion de pasturas degradadas incorporando conocimiento local de ganaderos de la Calzada Mopan, Dolores, Peten, Guatemala. *Agroforesteria en las Americas* **9** (35-36): 62-68

Hargreaves JN and Kerr JD (1992) BOTANAL – A comprehensive sampling and computing procedure for estimating pasture yield and composition. 2. Computational Package. Tropical Agronomy Technical Memorandum, CSIRO, Australia, Number 79, 83 pp

Haydock KP and Shaw NH (1975) The comparative yield method for estimating dry matter yield of pasture. *Australian Journal of Experimental Agriculture and Animal Husbandry* **15**: 663-670

Hoyos P, Garcia O y Torres M (1992) Método de disponibilidad de frecuencia – Evaluación con gramíneas postradas a nivel de finca. Guía práctica. CIAT, Cali-Colombia. 20 pp.

Ibrahim MA, Holmann F, Hernandez M and Camero A (2000) Contribution of Erythrina protein banks and rejected bananas for improving cattle production in the humid tropics. *Agroforestry Systems* **49**: 245-254

Jaramillo LH, Romero LCA, Duarte JH (2002) Evaluacion de la productividad y calidad de biomasa del nacedero (*Trichanthera gigantea*) establecido en asocio con cachimbo (*Erythrina fusca*) y mani forrajero (Arachis pintoe) a diferentes frecuencias de corte en la granja Las Brisas - Ibague. www.et.edu.co/investigacion.

Jimenez AJ, Alvarado GJ, Castro AH, Luna GLA, Mateus EH y Moreno JVM (2003) Establecimiento de Sistemas Silvopastoriles para clima calido, medio y frio de Norte de Santander. Boletines Tecnicos. Programa Nacional de Transferencia de Tecnologia Agropecuaria. MADR. Bucaramanga, Colombia.

Jimenez HJJ y Velasco BJL (2003) Evaluacion de la ganancia de peso en novillos de levante en sistemas silvopastoriles de estratos multiples en el Valle del Sinu. Tesis de pregrado. Universidad de Cordoba.

FAO (2004) FAOSTAT. Statistical Databases on line http://apps.fao.org/

Mahecha L, Rosales M, Molina CH, Molina E (1999) Evaluación de un sistema silvopastoril de pasto estrella, Leucaena y Algarrobo forrajero, a través del año, en el Valle del Cauca. En: Memorias VI Seminario Internacional sobre sistemas agropecuarios sostenibles. 28-30 de Octubre 1999. Realizado por la Fundación CIPAV y LA FAO. Cali, Colombia.

Mead DJ (1995) The role of agroforestry in industrialised nations: the southern hemisphere perspective with special emphasis on Australia and New Zealand. *Agroforestry systems* **31**: 143-156.

Ospina S (2005) Rasgos funcionales de las plantas herbáceas y arbustivas y su relación con el régimen de pastoreo y la fertilidad edáfica en Muy Muy, Nicaragua. MSc Tesis, Centro Agronómico Tropical de Investigación y Enseñanza-CATIE, Turrialba, Costa Rica**.**

Rivas L and Holman F (2005) Potential economic impact from the adoption of *Brachiaria* hybrids resistant to spittlebugs in livestock systems of Colombia, Mexico and Central America. *Livestock Research for Rural Development* **17** (5)

Roncallo, B., Barros, J., Baquero, L., Becerra, A. (2000) Producción animal con Acacia forrajera o Leucaena (*Leucaena leucocephala*) en el Valle del Cesar. Costa Ganadera p 5-10.

Roncallo Fandiño, B.A.; Rojas Alvarez, R. (1999) Evaluación del sistema silvopastoril natural algarrobillo (*Pithecellobium saman*) asociado con guinea (*Panicum maximum*) en el Valle del Cesar. Conference Seminario Técnico Tecnología para la Producción de Leche y Carne en Sistemas de Producción Bovina de la Región Caribe, Santa Marta (Colombia), Oct 1999. CORPOICA-COLCIENCIAS-FEDEGAN, Santa Marta (Colombia).

Restrepo SC (2002) Relaciones entre cobertura arborea en potreros y la produccion bovina en fincas ganaderas en el tropico seco, Cañas, Costa Rica. MSc Tesis, Centro Agronómico Tropical de Investigación y Enseñanza-CATIE, Turrialba, Costa Rica**.**

Restrepo-Saenz C, Ibrahim M, Harvey C, Harmand JM y Morales J (2004) Relaciones entre cobertura arborea en potreros y la produccion bovina en fincas ganaderas en el tropico seco en Canas, Costa Rica. *Agroforesteria en las Americas* (41-42):29-36

Rivas L and Holmann F (2005) Potential economic impact from the adoption of *Brachiaria* hybrids resistant to spittlebugs in livestock systems of Colombia, Mexico and Central America. *Livestock Research for Rural Development*: 17 (5)

Romero F, Montenegro J, Chana C, Pezo D y Borel R (1993) Cercas vivas y bancos de proteína de *Erythrina berteroana* manejados para la producción de biomasa comestible en el trópico húmedo de Costa Rica. *In:* S B Westley y M H Powell (eds). *Erythrina* in the New and Old Worlds. NFTA, Paia, Hawaii, U.S.A. pp. 205-210.

Souza de Abreu M.H., Ibrahim M., Harvey C. y Jiménez F. (2000) Caracterización del componente árboreo en los sistemas ganaderos de la Fortuna de San Carlos. Costa Rica. Agroforesteria de las Americas 7(26):53-56

Souza de Abreu MH (2000) Contribution of trees to the control of heat stress in dairy cows and the financial viability of livestock farms in humid tropics. PhD Tesis, Centro Agronómico Tropical de Investigación y Enseñanza-CATIE, Turrialba, Costa Rica**.**

Souza de Abreu MH, Ibrahim M and Jimenez F (¿??) Tree dispersed on pastures and dairy cattle performance in the humid tropics of Costa Rica.

Szott L, Ibrahim M and Beer J (2000) The Hamburger connection Hangover: Cattle, pasture land degradation and alternative land use in Central America. *Serie Tecnica. Informe Tecnico* N^{o}. 313.

Villanueva C y Ibrahim M (2002) Evaluación del impacto de los sistemas silvopastoriles sobre la recuperación de pasturas degradadas y su contribución en el secuestro de carbono en lecherías de altura en Costa Rica. *Agroforesteria en las Americas* **9** (35-36):69-74

Villacis J, Harvey C, Ibrahim M, Villanueva C (2003) Relaciones entre cobertura arborea y el nivel de intensificacion de las fincas ganaderas en Rio Frio, Costa Rica. *Agroforesteria en las Americas* **10** (39-40): 17-23

Wilson JR and Ludlow MM (1990) The environment and potential growth of herbage under plantations. In: *Forages for plantation crops* (Shelton HM and Stur WW. eds.). Proceedings of a workshop, Sanur Beach, Bali, Indonesia 27-29 June. pp10-24.

Young A (1997) *Agroforestry for Soil Management*. Second Edition. CAB International, Wallingford, UK

Zelada SEE (1996) Tolerancia a la sombra de especies forrajeras herbáceas en la zona Atlántica de Costa Rica. MSc Tesis, Centro Agronómico Tropical de Investigación y Enseñanza-CATIE, Turrialba, Costa Rica.

Appendix 8. List of the 60 papers that document patterns of animal diversity within pasture-dominated landscapes of Mesoamerica -Colombia and the animal taxa they provide information on. Synthesis papers are indicated by asterisks.

Citation	Landscape	Holdridge life zone	Taxa studied					
			Amphibians and reptiles	**Bats**	**Birds**	**Terrestrial mammals**	**Spiders and insects**	**Soil Microfauna**
Saad and Petit 1992.	Central, Belice.	Tropical wet forest			X			
Decaëns et al. 2004	Carimagua (CIAT-CORPOICA), Puerto Gaitán, Meta, Colombia.	Subtropical wet forest						X
Escobar and Chacón de Ulloa 2000.	RN La Planada, Ricaute, Nariño, Colombia.	Premontane wet forest					X	
Estrada and Fernández 1999.	RN La Planada, Ricaute, Nariño, Colombia.	Premontane wet forest					X	
Medina et al. 2002.	Filandia, Quindio and Pereira, Risaralda, Colombia.	Lower Montane wet forest					X	
Renjifo 2001.	Filandia, Quindio and Pereira, Risaralda, Colombia.	Lower Montane wet forest			X			
Barrantes and Pereira 2002.	the western slope of the Volcán Barva, Costa Rica.	Lower Montane wet forest			X			
Cárdenas et al. 2003	Cañas, Costa Rica.	Tropical dry forest			X			
Cohen and Lindell 2004.	Las Cruces, Coto Brus, Costa Rica.	Subtropical wet forest			X			
Daily et al. 2003	Las Cruces, Coto Brus, Costa Rica.	Subtropical wet forest				X		
Harvey et al. 2005.	Cañas, Costa Rica.	Tropical dry forest		X	X		X	
Holl 1998.	Las Alturas, Coto Brues, Costa Rica.	Lower Montane wet forest			X			
Hughes et al. 2002.	Las Cruces, Coto Brus, Costa Rica.	Subtropical wet forest			X			
Lang et al. 2003.	Rio Frio, Costa Rica.	Tropical wet forest			X			
Lindell and Smith 2003.	Las Alturas, Coto Brues, Costa Rica.	Lower Montane wet forest			X			
Lindell et al. 2004.	Las Alturas, Coto Brues, Costa Rica.	Lower Montane wet forest			X			

Appendix 8 Continued. List of the 60 papers that document patterns of animal diversity within pasture-dominated landscapes of Mesoamerica -Colombia and the animal taxa they provide information on. Synthesis papers are indicated by asterisks**.**

Citation	Landscape	Holdridge life zone	Taxa studied					
			Amphibians and reptiles	Bats	Birds	Terrestrial mammals	Spiders and insects	Soil Microfauna
Luck and Daily 2003.	Las Cruces, Coto Brus, Costa Rica.	Subtropical wet forest			X			
Powell and Bjork 2004.	Cordillera Tilaran Monteverde, Puntarenas, Costa Rica.	Lower Montane wet forest			X			
Ricketts et al. 2001.	Las Cruces, Coto Brus, Costa Rica.	Subtropical wet forest					X	
Schlaepfer 2003.	Volvan Baru, Coto Brus, Costa Rica.	Premontane wet forest	X					
Schlaepfer and Gavin 2001.	Las Cruces, Coto Brus, Costa Rica.	Subtropical wet forest	X					
Schonberg et al. 2004.	Cordillera Tilaran Monteverde, Puntarenas, Costa Rica.	Lower Montane wet forest					X	
Vaughan and Hawkins 1999.	Concepción de San Rafael de Heredia, Costa Rica.	Lower Montane wet forest				X		
Williams and Vaughan 2001.	Curu Wildlife Refuge, Nicoyan Peninsula, Costa Rica.	Tropical dry forest				X		
Horgan 2002.	University of El Salvador, La Paz, La Providencia, El Salvador.	Tropical dry forest					X	
Avendano-Mendoza et al. 2005.	Lachua region, Guatemala.	Tropical wet forest					X	
Zahawi and Augspurger 2006.	Pico Bonito National Park, Honduras, Honduras.	Subtropical wet forest			X			
Bojorges and López-Mata 2005.	Santa Gerturdis, Veracruz, Mexico.	Lower Montane wet forest			X			
Estrada and Coates-Estrada 2001.	Los Tuxtlas, Veracruz, Mexico.	Tropical wet forest		X				

Appendix 8 Continued. List of the 60 papers that document patterns of animal diversity within pasture-dominated landscapes of Mesoamerica -Colombia and the animal taxa they provide information on. Synthesis papers are indicated by asterisks.

Citation	Landscape	Holdridge life zone	Taxa studied					
			Amphibians and reptiles	**Bats**	**Birds**	**Terrestrial mammals**	**Spiders and insects**	**Soil Microfauna**
Estrada and Coates-Estrada 2005.	Los Tuxtlas, Veracruz, Mexico.	Tropical wet forest			X			
Estrada et al. 1994.	Los Tuxtlas, Veracruz, Mexico.	Tropical wet forest				X		
Estrada et al. 1997.	Los Tuxtlas, Veracruz, Mexico.	Tropical wet forest			X			
Estrada et al. 1998.	Los Tuxtlas, Veracruz, Mexico.	Tropical wet forest				X	X	
Estrada et al. 2000.	Los Tuxtlas, Veracruz, Mexico.	Tropical wet forest			X			
Estrada et al. 2002.	Los Tuxtlas, Veracruz, Mexico.	Tropical wet forest			X			
Galindo Gonzalez et al. 2000.	Los Tuxtlas, Veracruz, Mexico.	Tropical wet forest		X				
Galindo-Gonzalez and Sosa 2003.	Los Tuxtlas, Veracruz, Mexico.	Tropical wet forest		X				
Gove and Majer 2006.	Centro de investigaciones costeras La Mancha (CICOLMA), Veracruz, Mexico.	Subtropical wet forest					X	
Gove et al. 2005.	Los Tuxtlas, Veracruz, Mexico.	Tropical wet forest					X	
Graham 2001a.	Los Tuxtlas, Veracruz, Mexico.	Tropical wet forest			X			
Graham 2001b.	Los Tuxtlas, Veracruz, Mexico.	Tropical wet forest			X			
Graham and Blake 2001.	Los Tuxtlas, Veracruz, Mexico.	Tropical wet forest			X			
Graham et al. 2002.	Los Tuxtlas, Veracruz, Mexico.	Tropical wet forest			X			
Greenberg et al. 1997.	Ocosingo Valley, Chiapas, Mexico.	Tropical wet forest			X			

Appendix 8 Continued. List of the 60 papers that document patterns of animal diversity within pasture-dominated landscapes of Mesoamerica -Colombia and the animal taxa they provide information on. Synthesis papers are indicated by asterisks.

			Taxa studied					
Citation	**Landscape**	**Holdridge life zone**	**Amphibians and reptiles**	**Bats**	**Birds**	**Terrestrial mammals**	**Spiders and insects**	**Soil Microfauna**
Guevara and Laborde 1993.	Los Tuxtlas, Veracruz, Mexico.	Tropical wet forest			X			
Halffter and Arellano 2002.	Jalcomulco and Rancho Real Minero, 'Veracruz, Mexico.	Subtropical wet forest					X	
Martínez-Morales 2005.	Hildago, Mexico, Mexico.	Premontane wet forest			X			
Montiel et al. 2006.	Center for Technical Development TANTAKIN, Yucatan, Mexico.	Tropical dry forest		X				
Ortiz-Pulido et al. 2000.	Centro de investigaciones costeras La Mancha (CICOLMA), Veracruz, Mexico.	Subtropical wet forest			X			
Pineda and Halffter 2004.	La Antigua River basin, Xalapa - Veracruz, Mexico.	Tropical wet forest	X					
Pinkus-Rendón et al. 2006.	San Fernando, Chiapas, Mexico.	Tropical wet forest					X	
Urbina-Cardona et al. 2006.	Los Tuxtlas, Veracruz, Mexico.	Tropical wet forest	X					
Harvey et al. 2005.	Rivas, Belen, Nicaragua.	Tropical dry forest		X	X		X	
Harvey et al. 2006.	Rivas, Belen, Nicaragua.	Tropical dry forest		X	X		X	
Hernández et al. 2003.	Rivas, Belen, Nicaragua.	Tropical dry forest					X	
Medina et al. 2004.	Rivas, Belen, Nicaragua.	Tropical dry forest		X				
Medina et al. 2006.	Matiguas, Matagalpa, Nicaragua.	Subtropical wet forest		X				
Vilchez et al. 2004.	Rivas, Belen, Nicaragua.	Tropical dry forest			X			
Petit and Petit 2003.	Cerro Azul, Central Panama, Panama.	Premontane wet forest			X			
Total			**4**	**10**	**31**	**5**	**17**	**1**

Appendix 9. Summary of the methods used for sampling different animal taxa in each individual study (n = 65).

Taxa	Mist nets	Point counts	Bucket traps	Telemetry/ radio-tracking	Searches	Pitfall traps	pyrethrin fogging and knockdown	Tree beating	Sherman trap - Tomahawk traps	standard TSBF methodology	reference
Bats	X										Estrada and Coates-Estrada 2001.
Bats	X										Estrada and Coates-Estrada 2002.
Bats	X										Galindo Gonzalez et al. 2000.
Bats	X										Galindo-Gonzalez and Sosa 2003.
Bats	X										Harvey et al. 2005
Bats	X										Harvey et al. 2006.
Bats	X										Medina et al. 2004.
Bats	X										Medina et al. 2006.
Bats	X										Montiel et al. 2006.
Bats Total	**9**										
Terrestrial mammals									X		Daily et al. 2003
Terrestrial mammals					X						Estrada et al. 1994.
Terrestrial mammals					X						Estrada et al. 1998.
Terrestrial mammals				X							Vaughan and Hawkins 1999.
Terrestrial mammals					X						Williams and Vaughan 2001.
Terrestrial mammals Total				**1**	**3**				**1**		

Appendix 9 Continued. Summary of the methods used for sampling different animal taxa in each individual study (n = 65).

Taxa	Mist nets	Point counts	Bucket traps	Telemetry/ radio-tracking	Searches	Pitfall traps	pyrethrin fogging and knockdown	Tree beating	Sherman trap - Tomahawk traps	standard TSBF methodology	reference
Birds		X									Barrantes and Pereira 2002.
Birds		X									Bojorges and López-Mata 2005.
Birds		X									Cárdenas et al. 2003
Birds				X							Cohen and Lindell 2004.
Birds		X									Estrada and Coates-Estrada 2005.
Birds		X									Estrada et al. 1997.
Birds		X									Estrada et al. 2000.
Birds					X						Estrada et al. 2002.
Birds					X						Graham 2001a.
Birds					X						Graham 2001b.
Birds		X									Graham and Blake 2001.
Birds		X									Graham et al. 2002.
Birds		X									Greenberg et al. 1997.
Birds		X									Guevara and Laborde 1993.
Birds		X									Harvey et al. 2005
Birds		X									Harvey et al. 2006.
Birds					X						Holl 1998.
Birds		X									Hughes et al. 2002.
Birds		X									Lang et al. 2003.
Birds	X										Lindell and Smith 2003.
Birds	X										Lindell et al. 2004.
Birds		X									Luck and Daily 2003.

Appendix 9 Continued. Summary of the methods used for sampling different animal taxa in each individual study (n = 65).

Taxa	Mist nets	Point counts	Bucket traps	Telemetry/ radio-tracking	Searches	Pitfall traps	pyrethrin fogging and knockdown	Tree beating	Sherman trap - Tomahawk traps	standard TSBF methodology	reference
Birds		X									Martínez-Morales 2005.
Birds		X									Ortiz-Pulido et al. 2000.
Birds		X									Petit and Petit 2003.
Birds				X							Powell and Bjork 2004.
Birds		X									Renjifo 2001.
Birds		X									Saad and Petit 1992.
Birds		X									Vilchez et al. 2004.
Birds		X									Zahawi and Augspurger 2006.
Birds Total	**2**	**22**		**2**	**4**						
Spiders and insects						X					Avendano-Mendoza et al. 2005.
Spiders and insects						X					Escobar and Chacón de Ulloa 2000.
Spiders and insects						X					Estrada and Coates-Estrada 2002.
Spiders and insects						X					Estrada and Fernández 1999.
Spiders and insects						X					Estrada et al. 1998.
Spiders and insects								X			Gove and Majer 2006.
Spiders and insects						X		X			Gove et al. 2005.
Spiders and insects						X					Halffter and Arellano 2002.
Spiders and insects					X	X					Harvey et al. 2005
Spiders and insects					X	X					Harvey et al. 2006.
Spiders and insects					X	X					Hernández et al. 2003.

Appendix 9 Continued. Summary of the methods used for sampling different animal taxa in each individual study (n = 65).

Taxa	Mist nets	Point counts	Bucket traps	Telemetry/ radio-tracking	Searches	Pitfall traps	pyrethrin fogging and knockdown	Tree beating	Sherman trap - Tomahawk traps	standard TSBF methodology	reference
Spiders and insects						X					Horgan 2002.
Spiders and insects						X					Medina et al. 2002.
Spiders and insects					X	X					Pinkus-Rendón et al. 2006.
Spiders and insects			X								Ricketts et al. 2001.
Spiders and insects							X				Schonberg et al. 2004.
Spiders and insects Total			**1**		**4**	**13**	**1**	**2**			
Soil Microfauna										X	Decaëns et al. 2004
Soil Microfauna Total										**1**	
Amphibians and reptiles					X						Pineda and Halffter 2004.
Amphibians and reptiles					X						Schlaepfer 2003.
Amphibians and reptiles					X						Schlaepfer and Gavin 2001.
Amphibians and reptiles					X						Urbina-Cardona et al. 2006.
Amphibians and reptiles Total					**4**						
Total	**11**	**22**	**1**	**3**	**15**	**13**	**1**	**2**	**1**	**1**	

Appendix 10. Bibliography of papers on animal diversity within pasture-dominated landscapes of Mesoamerica and Colombia.

Avendano-Mendoza, Carlos.; Moron-Rios, Alejandro.; Cano, Enio-B.; Leon-Cortez, Jorge. 2005. Dung beetle community (Coleoptera: Scarabaeidae: Scarabaeinae) in a tropical landscape at the Lachua Region, Guatemala Biodiversity and Conservation. 14: 801-822

Barrantes, G.and Pereira, Ana. 2002. Seed dissemination by frugivorous birds from forest fragments to adjacent pastures on the western slope of Volcán Barva, Costa Rica. Revista Biologia Tropical. 50: 569-575

Bojorges-Baños, J. and López-Mata, L. 2005. Riqueza y diversidad de especies de aves en una selva mediana subperennifolia en el centro de Veracruz, México Acta Zoológica Mexicana. 21: 2005

Cárdenas, G.; Harvey, C. A.; Ibrahim, M. and Finegan, B. 2003. Diversidad y riqueza de aves en diferentes hábitats en un paisaje fragmentado en Cañas, Costa Rica. Revista Agroforestería en la Américas. 10: 78-85

Cohen, E.B. and Lindell, C.A. 2004. Survival, habitat use, and movements of fledgling White-Throated Robins (Turdus assimilis) in a Costa Rican agricultural landscape Auk. 121: 404-414

Daily, G. C.; Ceballos, G.; Pacheco, J.; Suzan, G. and Sanchez-Azofeifa, A. 2003. Countryside biogeography of neotropical mammals: Conservation opportunities in agricultural landscapes of Costa Rica Conservation Biology. 17: 1814-1826

Decaëns, T.; Jiménez, J.J.; Barros, E.; Chauvel, A.; Blanchart, E.; Fragoso, C. And Lavelle, P. 2004. Soil macrofaunal communities in permanent pastures derived from tropical forest or savanna . 103: 301-312

Escobar, F. and Chacón de Ulloa, P. 2000. Distribución espacial y temporal en un gradiente de sucesión de la fauna de coleópteros coprófagos (Scarabaeinae, Aphodiinae) en un bosque tropical montano, Nariño - Colombia Revista de Biología Tropical. 48: 961

Estrada, A.; Coates-Estrada, R. and Meritt, Jr, D. 1994. Non flying mammals and landscape changes in the tropical rain forest region of Los Tluxtlas, Mexico Ecography. 17: 229-241

Estrada, A. and Coates-Estrada, R. 2001. Bat species richness in live fences and in corridors of residual rain forest vegetation at Los Tuxtlas, Mexico Ecography. 24: 94-102

Estrada, A. and Coates-Estrada, R. 2002. Dung beetles in continuous forest, forest fragments and in an agricultural mosaic habitat island at Los Tuxtlas, Mexico Biodiversity and Conservation. 11: 1903-1918

Estrada, A. and Coates-Estrada, R. 2005. Diversity of Neotropical migratory landbird species assemblages in forest fragments and man-made vegetation in Los Tuxtlas, Mexico Biodiversity and Conservation. 14: 1719-1734

Estrada, A., Coates-Estrada, R. and Meritt, D.A. 1997. Anthropogenic landscape changes and avian diversity at Los Tuxtlas, Mexico Biodiversity and Conservation. 6: 19-43

Estrada, A.; Cammarano, P. And Coates-Estrada, R. 2000. Bird species richness in vegetation fences and in strips of residual rain forest vegetation at Los Tuxtlas, Mexico Biodiversity and Conservation. 9-10: 1399-1416

Estrada, A.; Coates-Estrada, R.; Dadda, A.A. and Cammarano, P. 1998. Dung and carrion beetles in tropical rain forest fragments and agricultural habitats at Los Tuxtlas, Mexico Journal of Tropical Ecology. 14: 577-593

Estrada, A.; Rivera, A.M.; and Coates-Estrada, R. 2002. Predation of artificial nests in a fragmented landscape in the tropical region of Los Tuxtlas, Mexico Biological Conservation. 106: 199-209

Estrada, C. and Fernández, F. 1999. Diversidad de hormigas (Hymenoptera: Formicidae) en un gradiente sucesional del bosque nublado (Nariño, Colombia) Revista de Biología Tropical. 47: 189-201

Galindo Gonzalez, J.; Guevara, S. and Sosa J,V. 2000. Bat- and Bird-Generated Seed Rains at Isolated Trees in Pastures in a Tropical Rainforest Conservation Biology. 14: 1693-1703

Galindo-Gonzalez, J. and Sosa, V.J. 2003. Frugivorous bats in isolated trees and rivarian vegetation associates with human mande pastures in a fragemented tropical landscape. The southwestern naturalist. 48: 579-589

Gove, A.D. and Majer, J. D. 2006. Do isolated trees encourage arboreal ant foraging at ground-level? Quantification of ant activity and the influence of season, in Veracruz, Mexico Agriculture Ecosystems & Environment. 113: 272-276

Gove, A.D.; Majer, J. D. and Rico-Gray, R. 2005. Methods for conservation outside of formal reserve systems: The case of ants in the seasonally dry tropics of Veracruz, Mexico Biological Conservation. 126: 328-338

Graham, C. and Blake, J.G. 2001. Influence of patch and landscape level factor on bird assemblages in a fragmented tropical landscape Ecological Applications. 11: 1709-1721

Graham, C.; Martinez-Leyva, J. E. and Cruz-Paredes, L. 2002. Use of fruiting trees by birds in continuous forest and riparian forest remnants in Los Tuxtlas, Veracruz, Mexico Biotropica. 34: 589-597

Graham, C.H. 2001. Factors Influencing Movement Patterns of Keel-Billed Toucans in a Fragmented Tropical Landscape in Southern Mexico Conservation Biology. 15: 1789-1798

Graham, Catherine. 2001. Habitat Selection and Activity Budgets of Keel-Billed Toucans at the Landscape Level The condor. 103: 776-784

Greenberg, R.; Bichier, P. and Sterling, J. 1997. Acacia, cattle and migratory birds in southeastern Mexico Biological Conservation. 80: 235-247
Guevara, S. and Laborde, J. 1993. Monitoring seed dispersal at isolated standing trees in tropical pastures: consequences for local species availability Vegetatio. 107/108: 319-338
Halffter, G. and Arellano, L. 2002. Response of Dung Beetle Diversity to Human-induced Changes in a Tropical Landscape Biotropica. 34: 144-154
Harvey, C. A.; Villanueva, C.; Villacis, J.; Chacon, M.; ;Muñoz, D., Ibrahim. M.; Gómez, Muñoz, D.; López, M.; Ibrahim, M.; Gomez, R.; Taylor, R.; Martinez, J.; Navas, A.; Saenz, J.; Sanchez, D.; Medina, A. Vilchez, S.; Hernandez, B.; Perez, A. Ruis, E.; Lang, I. and Sinclair, F.L. 2005. Contribution of live fences to the ecological integrity of agricultural landscapes. Agriculture, Ecosystems and Environment. 111: 200-230
Harvey, C.; Medina, A.; Sanchez, D.; Vilchez, S.; Hernandez, B.; Saenz, J.C.; Maes, J.M.; Casanoves, F. And Sinclair, F. 2006. Patterns of Animal Diversity in Different Forms of Tree Cover in Agricultural Lands Capes Ecological Applications. 16: 986-1999.
Hernández, B. ; J. M. Maes; Harvey. C. A.; Vílchez, S.; Medina, S. and Sánchez, D. 2003. Abundancia y diversidad de escarabajos coprófagos y mariposas diurnas en un paisaje ganadero en el departamento de Rivas, Nicaragua. Revista Agroforestería en la Américas. 10: 93-102
Holl, K. D. 1998. Do bird perching structures elevate seed rain and seedling establishment in abandoned tropical pasture? Restoration Ecology. 6: 253-261
Horgan, F. G. 2002. Shady field boundaries and the colonisation of dung by coprophagous beetles in Central American pastures Agriculture Ecosystems & Environment. 91: 25-36
Hughes, J. B.; Daily, G. C.; Ehrlich, P.R. 2002. Conservation of tropical forest birds in countryside habitats Ecology Letters. 5: 121-129
Lang, I.; Gormley, L. H.L.; Harvey, C.A. and Sinclair, F.L. 2003. Composición de la comunidad de aves en cercas vivas del Río Frío, Costa Rica. Revista Agroforestería en las Américas. 10: 86-92
Lindell, C. A.; Chomentowski, W. H. and Zook, J.R. 2004. Characteristics of bird species using forest and agricultural land covers in southern Costa Rica Biodiversity and Conservation. 13: 2419-2441
Lindell, C. and Smith, M. 2003. Nesting bird species in sun coffee, pasture, and understory forest in southern Costa Rica Biodiversity and Conservation. 12: 423-440
Luck, G. W. and Daily, G.C. 2003. Tropical countryside bird assemblages: Richness, composition, and foraging differ by landscape context Ecological Applications. 13: 235-247
Martínez-Morales, M.A. 2005. Nested species assemblages as a tool to detect sensitivity to forest fragmentation: the case of cloud forest birds OIKOS. 108: 634-642
Medina, A.; Harvey, C. A.; Sanchez, D.; Vilchez, S. and Hernandez, B.,. 2006. Bat Diversity and Movement in an Agricultural Landscape in Matiguás, Nicaragua Biotropica. : 40-41
Medina, A.; Harvey, C. A.; Sanchez, D.; Medina, A.; Vilchez, S. and Hernandez, B. 2004. Diversidad y composición de chiropteros en un paisaje fragmentado de bosque seco en Rivas, Nicaragua. Revista Encuentro de la Universidad Centroamericana. 68: 24-43
Medina, C.A.; Escobar, F. and Kattan, G. H. 2002. Diversity and habitat use of dung beetles in a Restored Andean Landscape Biotropica. 34: 181-187
Montiel, S.; Estrada, A. and Leòn, P. 2006. Bat assemblages in a naturally fragmented ecosystem in the Yucatan Peninsula, Mexico: species richness, diversity and spatio-temporal dynamics Journal of Tropical Ecology. 22: 267-276
Ortiz-Pulido, R.; Laborde, L. and Guevara, S. 2000. Frugivoria por Aves en un Paisaje Fragmentado: Consecuencias en la dispersion de semillas. Biotropica. 32: 473-488
Petit, L. J. and Petit, D. R. 2003. Evaluating the importance of human-modified lands for neotropical bird conservation Conservation Biology. 17: 687-694
Pineda, E. and Halffter, G. 2004. Species diversity and habitat fragmentation: frogs in a tropical montane landscape in Mexico Biological Conservation. 117: 499-508
Pinkus-Rendón, M.A.; León-Cortés, J.L. and Ibarra-Núñez, G. 2006. Spider diversity in a tropical habitat gradient in Chiapas, Mexico Diversity and Distributions. 12: 61-69
Powell, G.V.N. and Bjork, R.D. 2004. Habitat Linkages and the Conservation of Tropical Biodiversity as Indicated by Seasonal Migrations of Three-Wattled Bellbirds Conservation Biology. 18: 1523-1739
Renjifo, L.M. 2001. Effect of natural and anthropogenic landscape matrices on the abundance of subandean bird species Ecological applications. 11: 14-31
Ricketts, T.H.; Daily, G.C.; Ehrlich, P.R. and Fay, J.P. 2001. Countryside biogeography of moths in a fragmented landscape: Biodiversity in native and agricultural habitats Conservation Biology. 15: 378-388
Saad, V. and Petit, D. 1992. Impact of pasture development on winter bird communities in belize, central america. The Condor. 94: 66-71
Schlaepfer, M.A. 2003. Successful lizard eggs in a human-disturbed habitat Oecologia. 137: 304-311
Schlaepfer, M.A. and Gavin, T.A. 2001. Edge Effects on Lizards and Frogs in Tropical Forest Fragments Conservation Biology. 15: 1079-1090

Schonberg, L. A.; Longino, J. T.; Nadkarni, N. M.; Yanoviak, S. P. and Gering, J.C. 2004. Arboreal ant species richness in primary forest, secondary forest, and pasture habitats of a tropical montane landscape Biotropica. 36: 402-409

Urbina-Cardona, J.M.; Olivares-Pérez, M. and Reynoso, R.M. 2006. Herpetofauna diversity and microenvironment correlates across a pasture-edge-interior ecotone in tropical rainforest fragments in the Los Tuxtlas Biosphere Reserve of Veracruz, Mexico Biolo

Vaughan, C. S. and Hawkins, L. F. 1999. Late dry season habitat use of common opossum, Didelphis marsupialis (Marsupialia: Didelphidae) in neotropical lower montane agricultural areas Revista Biología Tropical. 47: 1-7

Vilchez, S.; Harvey, C. A.; Sanchez, D.; Medina, A. and Hernández, B.I. 2004. Diversidad de aves en un paisaje fragmentado de bosque seco en Rivas, Nicaragua. Revista Encuentro de la Universidad Centroamericana. 68: 60 -75

Williams, H.E. and Vaughan, C. 2001. White-faced monkey (Cebus capucinus) ecology and management in neotropical agricultural landscapes during the dry season Revista de Biología Tropical. 49: 1199-1206

Zahawi, R. A. And Augspurger, C.K. 2006. Tropical Forets Restoration: Tree Islands as Recruitment Foci in Degraded Lands of Honduras Ecological Applications. 16: 464-478