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Potential of Cocoa based Agroforestry for Biodiversity Conservation

Bachelor thesis

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Declaration

I, Matěj Zídek, declare that I have elaborated my thesis "Potential of Cocoa based Agroforestry for Biodiversity Conservation" independently and quoted only quotations listed in references.

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Abstract

Cocoa agroforestry does not provide only multiple incomes for smallholder farmes of tropical zone, more important is its potencial for conservation of biodiversity. Many famers do not realize that providing refuges for plant and animal is not just against their species extinction, but it is also advantageous for themselves. For instance many insects ensure pollination and reduction of pests as same as birds. Thanks to what farmers don´t need to apply big amount of pesticides, which greatly saves money. Also trees play very important role in terrestrial ecosystems and provide shade and range of products and services to rural people. Cacao tree is the undergrown plant, so shade is really important and helpful. It reduces nutritional stress in cocoa trees, thus fertilizers not have to be used and also helps to suppress undesirable light, soil erosion, the presence of invasive weeds and other trees also work as wind breakers. In my study I tried to proof how important biodiversity conservation is and how it cocoa agroforestry conserving compared to primary forest and full-sun farming.

Key words: Cocoa agroforestry, forest conservation, landscape conservation, monoculture, plant and animal diversity, cacao tree (*Theobroma cacao*)

Abstrakt

Kakaovníkové agrolesnictví neposkytuje pouze více typů příjmů drobným zemědělcům v tropech, důležitější je jejich potenciál pro zachování biodiverzity. Mnoho zemědělců si neuvědomuje, že poskytování útočišť pro rostlinné a živočišné druhy nepomáhá pouze proti vymírání druhů, ale má také výhody pro ně samotné. Například mnoho druhů hmyzu zajišťuje opylování a redukuje výskyt škůdců, stejně jako mnoho ptáků. Díky čemuž farmáři nepotřebují aplikovat velké dávky pesticidů, což významně snižuje výdaje. Také stromy hrají velmi důležitou roli v pozemních ekosystémech, kde poskytují stín a množství produktů obyvatelům venkova. Kakaovník je podrostová dřevina, stín je pro ní tedy velmi důležitý a užitečný. Snižuje nutriční stres, a proto nemusí být používána hnojiva, také pomáhá potlačovat nežádoucí světlo, půdní erozi, přítomnost invazivních plevelů a spolu pěstované dřeviny fungují jako větrolamy. V mé studii jsem se snažil dokázat, jak důležité je zachování biodiverzity a jak jí kakaovníkové agrolesnictví zachovává v porovnání s původním pralesem a naopak intenzivním zemědělstvím.

Klíčová slova: Kakaovníkové agrolesnictví, ochrana lesů, zachování krajiny, monokultura, rozmanitost rostlin a živočichů, Kakaovník (*Theobroma cacao*)

Table of contents

List of Tables and Figures

1. Introduction

Agroforestry systems, renowned for their high tree species richness and complex vegetation structure, stand out as promising biodiversity conservation tools. Well-known examples include shaded coffee (*Coffea* spp.) and cocoa (*Theobroma cacao*) plantations, homegardens, rubber and fruit tree agroforests (Somarriba et al., 2004).

Due to high inputs, agriculture has developed a lot during the last two decades, but developments haven't been only positive. It is also accompanied by soil degradation, biodiversity decline and environmental pollution with negative feedbacks on food security and farm incomes at local scales (Perfecto and Vandermeer, 2008). The decline in biodiversity has disrupted ecological interactions and dramatically increased the reliance of agricultural production on external inputs. In contrast, diversification of agroecosystems to enhance agrobiodiversity and ecological processes can simultaneously support biodiversity conservation and the delivery of a range of supporting, provisioning and regulative ecosystem services that enhance the sustainability and residence of agricultural systems (Knoke et al., 2009).

Cocoa (*Theobroma cacao*) growing is generally seen as one of the factors in the deforestation of humid tropical zones. 3.5 million producers in the South supply 4 million tonnes of cocoa (Table 1), which are primarily consumed in the North; cocoa growing covers almost 10 million hectares worldwide (CIRAD, 2013).

The center of origin of the cocoa tree probably is on the eastern equatorial slope of the Andes and undoubtedly is in the Amazon basin. The oldest real center of cultivation seems to have been Central America, where the crop has been under cultivation for more than 2,000 years (Cope, 1976).

Cocoa agriculture has played an important role in the transformation of lowland tropical forest landscapes in Latin America, Africa and Asia over the past centuries and continues to do also today. Cocoa is now grown in some 50 tropical countries, with smallholder farmers growing most of the world's production (Lass, 2004). In many regions, cocoa has been a driver of deforestation, with cocoa grown in plantations or agroforestry systems replacing the original forest ecosystems (Ruf and Schroth, 2004). However, in comparison to other land uses that replace intact forest, traditional cocoa agroforests with diverse and structurally complex shade canopies are among the agricultural land uses that are most likely to conserve a significant portion of the original forest biodiversity (Rice and Greenberg, 2000).

Cacao trees can be very well intercropped with other cash or food crops, which thus form heterogeneous and biodiverse agroforestry systems. Because it takes 3-6 years before cacao trees become productive, intercropping is an existential necessity for many small-holder farmers to grow food and generate income for the time cacao trees are not yet productive. Examples are vegetables (*e.g.*, cassava), spices (*e.g.*, peppers, vanilla), timber and fruit trees (*e.g.*, teak, avocado, sugar palm). This type of cacao agroforests is most common after previous forms of agricultural use (*e.g.*, rice paddies, cornfields, coffee plantations, oil palm plantations) (Anhar, 2005).

Table 1 World production of cocoa beans

	2010/11		Estimates 2011/12		Estimates 2012/13	
Africa	**3224**	**74.8%**	**2919**	**71.6%**	**2813**	**71.6%**
Cameroon	229		207		225	
Côte d'Ivoire	1511		1486		1445	
Ghana	1025		879		835	
Nigeria	240		235		225	
Others	220		113		83	
America	**561**	**13.0%**	**650**	**15.9%**	**618**	**15.7%**
Brazil	200		220		185	
Ecuador	161		193		192	
Others	201		237		240	
Asia & Oceania	**526**	**12.2%**	**510**	**12.5%**	**500**	**12.7%**
Indonesia	440		440		420	
Papua New Guinea	48		39		41	
Others	39		32		39	
World total	**4312**	**100.0%**	**4080**	**100.0%**	**3931**	**100.0%**

Source: ICCO Quarterly bulletin of cocoa statistic, cocoa year 2012/13

2. Objectives and Methodology

The main objective of the study is to assess the consequence of cocoa agroforestry for biodiversity conservation and differences in biodiversity among intensive cocoa production and traditional mixed crop system. This study is conceived as literature review. Information were collected from main scientific web databases Scopus (http://www.scopus.com), Web of Knowledge (http://sub3.webofknowledge.com), Science Direct, etc., specialized books, and scientific journals. Main topics of searched articles were about cocoa based agroforestry and their overall impact on plant, animal and insect and species richness.

3. Literature review

3.1 Cocoa agroforestry systems

The natural habitat of the cacao tree is the understory of humid lowland rainforests in the Amazon basin, which explains the need of shade of cultivated cacao trees at least at a young stage. Cacao agroforestry systems that have reached the productive stage vary widely in terms of management intensity and the presence, density and composition of shade tree stands (Urquhart, 1955).

In all cocoa producing regions, agroforestry systems can be found that have dense shade cover (>60%) provided by a diversity of trees that remains from the previous rainforest cover (Bos *et. al.,* 2007; Faria *et. al.,* 2007). Such structurally rich “chocolate forests” are a common pioneer form of agricultural land use after expansion into pristine rainforests. As such, these “rustic” agroforestry systems are a sustainable alternative to slash-and-burn practices in which all forest cover is lost previous to agricultural expansion (Rice and Greenberg, 2000). However, the key reason of expansion into forestland is that it is more lucrative than replanting in existing plantations because of cheaper labour and the presence of soil nutrients (Ruf and Schroth, 2004), which makes the expansion of cocoa production one of the causes of ongoing forest degradation.

3.1.1 Definition of Agroforestry

Agroforestry is a summary term for practices that involve the integration of trees and other large woody perennials into farming systems through the conservation of existing trees, their active planting and tending, or the tolerance of spontaneous tree regrowth (Schroth et al., 2004). Following a recent definition by the World Agroforestry Center (ICRAF, 2000), agroforestry is defined here as a dynamic, ecologically based natural resource management practice that, through the integration of trees and other tall woody plants on farms and in the agricultural landscape, diversifies production for increased social, economic, and environmental benefits.

Agroforests do not require any sophisticated technology or sophisticated technical know-how: their establishment and management call on very simple techniques which all shifting cultivators in humid tropical countries have at their disposal (de Foresta and Michon, 1993).

It is important to understand that agroforests are not specifically conceived by farmers to allow biodiversity conservation: biodiversity restoration in agroforests results mainly from unintentional processes. But, whatever the conception, the main economic role or the geographical location of existing agroforests, the same conclusion remains: agroforest structure and management strategy allows to "capture" and "fix" plant and animal biodiversity. In fact, biodiversity in agroforests results from two types of dynamics. The first one derives from the plantation of useful tree species - which recreates the skeleton of a forest system and acts as a catalyst for further biodiversity installation in the agricultural lands, newly established agroforest structures create suitable environment and convenient niches for the establishment of forest plant species carried from the neighbouring forests through natural dispersion, and offers shelter and feed to forest animals. As spontaneous vegetation and fauna starts establishing, the original structure diversifies, which enhances further establishment of diversified flora and fauna as in any silvigenetic process. In this natural enrichment process, man only selects among the possible options given by ecological processes (selecting and/or introducing economic trees and protecting their development) thus favouring resources, but non-resources are also establishing and reproducing as far as they are not considered as "weeds" by farmers. And after several decades of such a balance between free functioning and integrated management, the global biodiversity levels are fairly high and reconstitute the true forest aspect of the agroforest. (Apart from major species, either cultivated or selected and protected, which form the frame of the agroforest, the spontaneous component of an agroforest may represents up to 50% of the tree stand alone, not taking into account liana, epiphyte and undergrowth species. Agroforests often shelter several tens of commonly managed tree species, but also several hundred additional species, spontaneously established and often used (Michon & de Foresta, 1992).

During the last twenty years, agroforestry systems and technologies have played a more and more significant role in the definition and implementation of sustainable development of rural areas in the tropics. This role does not only imply research on modern technologies or promotion of new crops and trees associations, but also the acknowledgment of indigenous agroforestry practices as important bases for the development of these modern technologies and associations. However, it is often inappropriate and misleading to speak of "agroforestry" in general. It is commonly acknowledged for example that agroforestry is essential for soil conservation or rehabilitation, especially in ecologically fragile areas.

It is therefore important to understand that agroforestry does not represent a uniform ensemble of systems and technologies and that the global qualities commonly attributed to agroforestry practices are not always observed (Michon & de Foresta, 1995).

Through those years have been evolved two main types of agroforestry, namely, the distinction between "simple" and "complex" agroforestry systems.

Simple agroforestry systems represent associations of a small number of components, usually no more than five tree species and an annual species (paddy, maize, vegetables, forage herbs) or a treelet (bananas, cocoa, coffee). These simple associations most often concern the "agro-" facet of agroforestry, and the best-documented form of "simple" agroforestry is alley-cropping. A famous simple agroforestry systems also concerns forestry, more precisely silviculture: the taungya system for the establishment of forest plantations. These simple agroforestry associations represent what can be called the "classical" agroforestry model as it is the most favoured in research and development program of most institutions dealing with agroforestry.

In complex agroforestry systems, a high number of components (trees as well as treelets, liana, herbs) are intimately associated, and the expression as well as functioning of such systems is close to those observed for natural forest ecosystems, either primary or secondary forests. Because of the dominance of tree components, of high plant diversity and of forest-like structure and functioning, these complex systems, which we define as „agro-forests“, seem to concern more forestry scientists than agriculturists. However, they are not at all alien to tropical agriculture practitioners: agroforests characterize many peasant agriculture in the humid tropics (Michlon & de Foresta, 1995).

3.1.2 Types of cocoa farming

Farmers used to grow cacao in shade tree agroforestry systems in the past by using beneficial trees for the cacao plants as well as for the farmer (Gyampoh, 2011).

There are different forms of shade management systems employed in cocoa cultivation. Whilst Ruff and Zadi (1998) recognise that mature cocoa farms can be classified into six types of shade management systems:

1. Selected jungle trees saved by selective cutting and partial burning. In this case, the shade trees form a stratum 20 – 40 metres above the cocoa groves
2. Spontaneous and selected regrowth of jungle trees previously cut down (and burnt but the fire does not destroy the entire root system). The shade stratum is much lower than in the previous case,
3. Trees planted by farmers. The most frequent are leguminous trees supposed to have a positive impact in terms of shade and nitrogen supply,
4. Tree-crops such as various fruit trees planted for direct agricultural and economic purposes but which may also provide some shade and wind breaks to cocoa,
5. Plantains and bananas which are supposed to provide only temporary shade to young seedlings but in a number of situations mats regenerate every year,
6. Zero shade' systems or strict monoculture after complete forest clearing and regular elimination of any shoots during weed control,

Rice and Greenberg (2000), however, identify three basic shade management systems in cocoa:

1. Rustic cocoa management: This is widespread in humid West Africa and local in Latin America and is characterised by the planting of cocoa under the canopy of thinned or older secondary forest;
2. Planted shade systems: These vary widely and range from:
   a. Traditional polycultural system – having multiple species of planted shade trees with occasional remnant forest species,
   b. Commercial shade – where other crop trees are interspersed among planted shade trees and the cocoa,
   c. Monocultural specialized shade – where the shade is dominated by one or a few tree species or genus. Some indigenous shade systems are truly diverse agroforests. However in most planted systems where a multitude of shade

species is found, generally one or a few species comprise the “backbone” shade in which other fruiting and timber species are inserted. In some areas, cocoa is grown under or intercropped primarily with fruit trees;

3. Zero-shade cocoa or technified cocoa systems without shade – cultivation, without shade, is common in Malaysia and is becoming more widespread in parts of Colombia and Peru.

A study by Freud *et al* (1996) into the levels of permanent shade in cocoa farms in Ghana and Côte d’Ivoire showed that about 50% of the total cocoa area in both countries was under mild permanent shade whilst an average of about 10% in Ghana and 35% in Côte d’Ivoire was under no shade; indicating a gradual shift towards eliminating shade trees from the cocoa agroecosystem.

On the folowing table we can see differences between cocoa cultivating techniques.

Table 2 Comparison of cultivation techniques in different factors (Daniels, 2006)

FARM MODEL	FARM ESTABLISHMENT	REHABILITATION & REPLANTING	PEST & DISEASE CONTROL	AVE COCOA YIELD & LIFE SPANS	COCOA VARIETIES
Diverse cocoa agro-forest	a) Forest is thinned to make space for cocoa planting. b) Forest species are left and the canopy remains largely intact c) Land cleared by hand	Seedlings are planted in light gaps; improved varieties grafted onto existing trunks	Cultural controls, biological controls, low use of inputs, some use of copper fungicides	300kg/ha Up to 60 yrs	Traditional varieties
Selective shade cocoa	a) Cocoa planted under remaining forest and introduced trees; b) or a mix of cocoa, shade and agroforestry crops are planted on cleared land; c) land cleared by slash and burn in some cases	Old, unproductive trees are removed; seedlings planted in light gaps; improved varieties grafted onto existing trunks	Moderate use of fungicides and pesticides	500-2500kg/ha depending on intensity of management 9-20 yrs	Mix of use of traditional and improved varieties
Full sun cocoa	a) Cocoa planted on cleared forest land or on degraded land under shade of food crops or fruit trees b) land cleared by slash and burn	Unproductive trees removed when yields decrease or used for side grafting new planting material (8-20 yr cycle depending on variety used)	Regular use of pesticides and fungicides; disease and pest-resistant varieties	2500-4500kg/ha 6-20 yrs	High yielding, disease resistance hybrids

FARM MODEL	PLANTING DENSITY	INTERPLANTED SPECIES / SECONDARY CROPS	SHADE CANOPY	SHADE MANAGEMENT
Diverse cocoa agro-forest	Cameroon: Timber species 6-7 trees/ha in >10m strata Fruit trees at 4 trees/ha Brazil: 68-76 upper canopy trees/ha 724-1000 cocoa trees/ha	Timber, fruit, medicinal plants, food crops such as: Cameroon: native African palm, citrus Brazil: rosewood, brazilwood, cedars Costa Rica: banana, plantain, laurel, guaba	Multi-strata of primary and secondary forest species; up to 50 species forming a closed canopy; >10 forest remnant species; upper strata 20-40m; structural complexity; high floristic diversity; 40-70% shade cover	Intermittent pruning of lower canopy trees; occasional felling of timber and shade trees
Selective shade cocoa	Ghana/Cote d'Ivoire: Cocoa 3x3 spacing 1111 trees/ha Fruit trees 24x24m (34 trees/ha) Timber 12x12m later thinned to 24x24m	Timber, fruit and food crops such as: Ghana: orange, avocado pear Ecuador: banana, cassava, papaya, maize, citrus, *Inga*	20-40% shade cover; some forest remnants mixed with planted fruit and timber species; Upper stratum 20m or less;	Shade is thinned or cleared to encourage productivity
Full sun cocoa	Malaysia/Philippines: 2000-4000 cocoa trees/ha 1:1 planting of food crops and cocoa seedlings	Fruit and food crops are used to shade cocoa seedlings and removed when cocoa matures Cote d'Ivoire: plantains, yams, taro, etc	Shade used only for cocoa seedlings, removed when cocoa matures	Cocoa canopy is kept low for ease in harvesting and pest/disease control

3.1.3 Full-sun cocoa production

Cocoa has been grown as monoculture without shade in many regions over its commercial history and in recent years, more cocoa plantations are being managed intensively and in full sun. The literature suggests that most cocoa growing regions have at one time or another experimented with full sun cultivation and that sooner or later they all have to return to a modicum of shade and agroforestry practices to rebuild ecological resources and renovate cocoa productivity (Daniels, 2006).

In Côte d'Ivoire, Ruf and Zadi (1998) conclude that two to three generations of full sun cocoa cultivation has caused considerably more environmental damage than shade farming would have and that it may have had negative effects on rainfall patterns and overall ecosystem functioning.

Two sources surveyed indicate that full sun cultivation could be sustainable under certain circumstances (Clay 2004, Ruf and Zadi 1998). Full sun cocoa can yield as much as three times that shaded cocoa, however the full sun plantation must be completely renovated much sooner (at 10-20 y. vs. 40-60 y.) than a shaded plot (Beer 1987, Ruf and Zadi 1998). This is mostly caused because of the leaves of cocoa trees are directly exposed to the rays of the sun which lead to much higher evapotranspiration and it could lead to moisture stress in the system and that constantly damaging trees which are originally undergrowth plants (Murray, 1975). Full-sun production also requires agrochemical inputs and constant management to realize maximum yield potential. The costs are higher °however the efficiency (cost/yield/ha) may be higher as well with sufficient farmers' education, available and affordable planting material and inputs (Daniels, 2006).

Upper Amazonian hybrids were introduced to West Africa in the 1950s but were not used on a widespread scale until the 1970s. These varieties were intended to be grown under full sunlight and exhibited a shorter maturity and overall productive life. These varieties can also be grown on less suitable soils such as the stony soils of the Soubré region of Cote D'Ivoire which has expanded the forest frontier in this country (Ruf and Zadi 1998). Their productive lifespan was approximately 20 years under full sun however they may be able to live up to 60 years under mild shade and a regime of fertilizers and pesticides. Full sun cocoa is more susceptible to pest and disease outbreaks. On the island of Sao Tome in the 1920s, cocoa farmers eliminated their shade canopy in an effort to boost yields. They suffered a pest outbreak soon afterwards and much of the country's cocoa crop was wiped out (Johns, 1999).

Research table 2 shows influence of unshaded cocoa production in Ghana on soil nutrients content. Due to this and also other important results and reasons, full-sun cocoa production must be under constant maintenance.

Table 3 Effect of land use types on selected soil properties (0-15cm depth) (Ofori-Frimpong)

SOIL PROPERTY	REMNANT FOREST	SHADED COCOA(MEDIUM)	SHADED COCOA(HEAVY)	UNSHADED COCOA
PH	5.1	6.4	6.3	6.3
%Carbon	4.0	2.8	2.4	1.7
% Nitrogen	0.46	0.33	0.24	0.19
Available P (μg/g)	24.1	22.4	15.5	9.9

3.1.4 Traditional cacao farming system

3.1.4.1 Cabruca system – Brazil

Brazil is the world's fifth largest cocoa producer. The majority (98%) of Brazil's cocoa is produced in the state of Bahia, home to the valuable and extremely threatened Atlantic rainforest ecosystem. An estimated 2-7% of the original Atlantic rainforest remains and much of it contains heavily shaded cocoa farms with high canopy, indigenous forest tree species known as 'cabruca' or 'cabrucagem' systems (Johns 1999, Donald 2004). Cabruca style planting is also profitable because it requires less investment per unit area than the clear-cut method favored by smallholders (Ruf and Schroth, 2004).

Brazil developed plantations without completely destroying the native rainforest ecosystem. Large landowners in Bahia planted their cocoa under native shade (i.e. the cabruca system) and maintained sections of their farms as forest (Donald 2004). In the cabruca system the farmer thins out select larger trees, lower canopy trees and herbaceous plants and plants cocoa under the remaining canopy. The cabruca system is characterized by 50-60% shade cover with overhead tree counts of 68-76 trees/ha and approximately 724 cocoa trees/ha (Rosand et al. 1985). Native timber species, which have disappeared in non-cocoa areas, are found in cabruca farms as shade trees. These include rosewood (*Dalbergia nigra*), brazilwood (*Caeselapinia esplinata*), jequitibá (*Cariniana brasiliensis*) and cedro (*Cedrela odorata*) (Johns 1999, Rosand et al. 1985). Cocoa trees were left virtually untouched until they bore fruit, allowing other vegetation to grow up between rows. The density and altitude of the cabruca canopy and the large-scale farms have conserved forest resources partly by preventing squatter settlement and forest clearing. The farms are host to considerable biodiversity. The endangered golden lion tamarin monkey and a previously unknown bird species have both been found in cabruca agroecosystems (Johns 1999).

3.1.5 Influence of shade on cocoa trees cultivation

Cocoa tree is originally an under-grown tree crop from the Amazon Forest and tolerates a considerable degree of shade. The origin of the use of shade is usually attributed to early cultivators mimicking the natural sub-canopy environment of wild cocoa trees in the forest (Murray, 1958) of the upper Amazon and Orinoco river basin (Simpson & Ogorzaly, 1986).

The tree grows well in combination with other tree species that give shade to the cacao trees and provide other benefits for the farmer, like food, fruit, timber and fuel wood. Extreme climatic conditions (e.g. high difference in temperature, wind velocity, soil moisture or temperature and light availability) causes stress to the cocoa tree and nutritional imbalances in the soil within a few years. Too much light may cause overbearing of fruits and excessive vegetative growth which in turn creates nutritional imbalances and dieback of cocoa trees (Beer et al, 1998).

Because of these conditions the production of cocoa under full-sun seems to be unsustainable. The unsustainable production of cacao beans leads to vulnerable trees that need more and more chemical fertilizers and pesticides to survive. Nearly a third of the crops are destroyed each year due to pest and disease pressure, meaning a total loss of $2.4 billion annually (Guyton et al, 2003).

Consequences that arise from this full-sun production method cause also serious environmental problems, such as ozone layer depletion, freshwater pollution and human toxicity (Afrane and Ntiamoah, 2007).

Figure 1 provides an overview of the productivity of cocoa in shade- and full-sun grown farms over a period of eighty years. It seems that un-shaded hybrid cocoa system production is almost twice as much compared to the shaded traditional system. However, according to the research of Obiri et.al., (2006), production of the un-shaded hybrid system starts to decline within 10 to 15 years while the production of the traditional systems starts decreasing after 25 years. The economic rotation age is only eighteen years for an un-shaded hybrid cocoa system, while this is twenty-nine years when shaded.

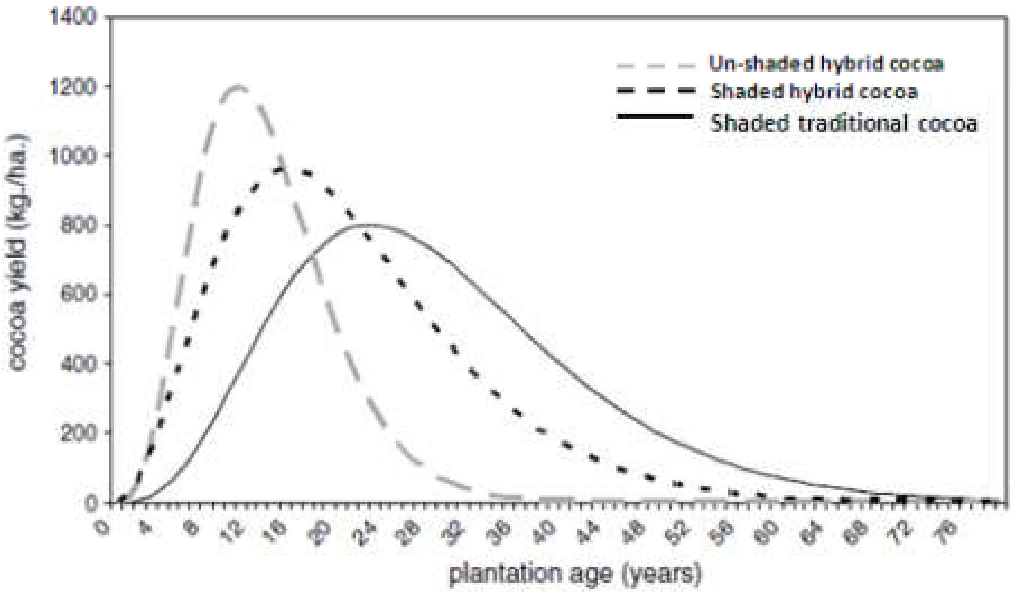

Figure 1 Cocoa yield patterns in un-shaded hybrid, shaded hybrid and traditional shaded systems. (Obiri et al, 2006).

Moisture stress due to higher evapo-transpiration and the lower nutrient concentrations in the soils due to overbearing of fruits make the cocoa trees more susceptible to incidence of pest and diseases (Ofori-Frimpong et al.). Shade trees are able to reduce plant stress by improving the climatic conditions (e.g. reduction of air and soil temperature extremes, reduction of wind speeds and buffering of soil moisture and fertility). It seems that shade promotes the long-term production of older cocoa plants with low levels of fertilization. Cocoa trees that grow under less than optimum shade have a shorter life cycle where shaded cocoa trees may produce for 60 – 100 years under certain soil and rainfall conditions (Ruf and Zadi, 1998).

The different species develop a certain equilibrium between pests or diseases and their natural enemies. This balance is an important aspect of biological and integrated pest management. A more diverse system reduces the risk for weeds and diseases as it might attract more natural enemies and wherein certain species can function as barrier against the spread of pests. Insects or pests that damage a particular crop can be driven away by substances that other crops produce or by the other crop's attraction of insects that eat the damaging organisms. However, the advantage of the shade trees is only to a certain extent as some weeds and diseases might increase under shady circumstances while others might be promoted. Some tree species might even function as host for pests, which makes it very hard and important to select the right species to intercrop with. (Schroth et.al., 2000; van Schöll and Nieuwenhuis, 2004).

Shading trees in a cocoa farm is not just positive, some disadvantages could be observed. Here we can see three most often caused cases. The risks to attract more pests and diseases, damage by falling branches and competition with cocoa trees are mostly quoted as negative argument. There are more other disadvantages, but these are not so harmful and important. (Hoogendijk, 2012)

3.1.5.1 How shade affects biodiversity conservation

Firstly, forest clearance for cocoa threatens biodiversity by degrading both the physical structure and species diversity of the canopy, and increasing the fragmentation of the landscape. Once forests are cleared, however, cocoa farms have positive benefits especially when grown under the shade of secondary forest or other species-rich tree canopies because they provide a wider array of ecological niches for wildlife than do many other cultivated landuses (Leakey & Tchoundjeu, 2001). In terms of their architecture and ecology, many traditional shaded coffee and cocoa plantations resemble natural forest more than most other agricultural systems (Beer *et al.*, 1998).

Considerable research has been directed at the potential for shade crops, such as coffee and cocoa in maintaining otherwise lost biodiversity in deforested landscapes (Estrada *et al.,* 1997; Greenberg *et al.,* 2000; Reitsma *et al* 2001). Such habitats can enhance the existence and maintenance of biological diversity by providing additional habitat and resources for organisms visiting from intact forest, or they can support forest-dependent organisms throughout the annual cycle. In the latter case, shade crops provide a refuge for biodiversity in areas that have lost most or all of their natural forests. In the former, shade crops could be useful as a buffer zone crop for forest reserves (Greenberg *et al.,* 2000). Greenberg *et al* (2000) also point out that planted coffee and cocoa ‘forests’ are a mode of reforestation that could provide both revenue for local land owners as well as wildlife habitat. Cocoa is sometimes cultivated under thinned forest canopy (rustic cocoa), but more often it is found beneath a diverse canopy of planted shade trees (planted shade) and these alternative systems probably support very different level of diversity of tropical forest organisms (Greenberg *et al.,* 2000). They can serve as pathways or stopover points for the migration of animal species between natural reserves (Beer *et al.,* 1998; Rice and Greenberg, 2000). When native trees are used as shade trees in a buffer zone, a larger gene pool of these species can be maintained than would be possible in the protected area alone (Beer *et al.,* 1998)

A wider diversity of tropical forest organisms occurs in shaded cocoa plantations than in most other lowland tropical agricultural systems. Rustic plantations incorporating natural forest shade trees are probably the best in this regard. However, to the degree that these rustic systems are not stable, they may not provide in the long term. Cocoa grown under planted shade may provide the best long-term protection for tropical forest biodiversity (Rice and Greenberg, 2000).

The following table refers about impact of different types of cocoa growing for biodiversity richness or looses.

Table 4 Biodiversity characteristics of shade use farms. Sulawewsi, indonesia (Siebert, 2002)

	Number of species					
Site/description	Trees	Epiphytes	Lianas	Ground	Weeds	birds
Primary forest /cacao (2 years)	30	31	2	7	3	ND*
Secondary forest / coffee (25 years)	25	21	1	2	9	22
Secondary forest /cacao (3 years)	25	21	4	3	5	ND
Full-sun cacao/G. sepium (1 year)	1	0	0	0	16	0
Agroforestry /cacao (10 years)	7	0	0	9	5	ND

*ND – no data

3.2 Biodiversity conservation

Biodiversity conservation provides substantial benefits to meet immediate human needs, such as those for clean, consistent water flows; protection from floods and storms; and a stable climate (Conservation International, 2014)

Tropical ecosystems are exceptionally rich and exclusive reservoirs of much of the biodiversity on Earth. However, the rapid and extensive destruction of tropical habitats has become a serious threat to their native biota (Laurance, 1999).

Conservationists therefore seek to promote the creation of protected areas in which human activity is severely restricted, with a strong focus on those areas in the world containing the most, and the most unique biodiversity (Myers et al. 2000).

Two main global strategies in conservation efforts are commonly used, one that incorporates threats and one that uses ecological representation. The first type of global conservation strategy focuses attention on the areas and biota that are most threatened and most distinctive. The hotspot approach of Conservation International is an example of this type of global conservation strategy (Mittermeier et al., 2000). Hotspots are land areas with more than 0.5 percent of all vascular plant species endemic to them and with at least a 70 percent loss of their natural primary habitats (Schroth et al., 2004).

On the Earth are 25 identified hotspots (Figure 2), which cover 11.8 percent of the land surface, but because of habitat destruction, natural primary habitat in these areas covers only 1.4 percent of the earth’s land surface. These areas provide the only remaining habitat for an estimated 44 percent of all species of vascular plants and 35 percent of all species of mammals, birds, reptiles, and amphibians. Many species in the hotspots are extremely vulnerable, with diminished populations, highly fragmented habitat, and pressures from numerous human sources (Myers et al., 2000).

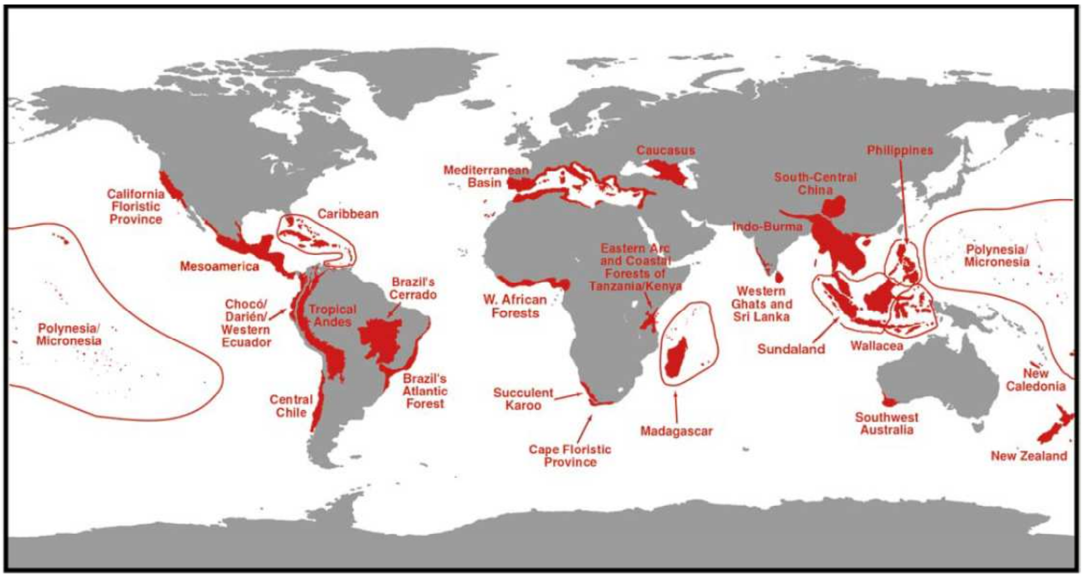

Figure 2. 25 hotspots around the World. The hotspot expanses comprise 30±3% of the red areas (Myers et al., 2000).

The following principles have been culled from the reviewed literature on a system of cocoa cultivation that conserves biodiversity.

- Integrate biodiversity and productivity objectives in farm planning
- Assess local knowledge and rural dynamics
- Select and multiply quality cocoa and companion tree varieties
- Maintain floristic and structural diversity in canopy and include native species
- Maintain constant canopy cover for microclimate stability
- Maintain diverse flora such as epiphytes, lianas, and vines that provide habitat niches
- Increase domestication and marketing of non-wood forest products (NWFPs)
- Develop and market by-products
- Promote farm products for the biological and/or certified product market
- Limit access of domesticated animals to agroforest
- Connect cocoa agroforests and forest patches to create green corridors
- Research carbon sequestration and conservation payments
- Promote and maintain synergy and feedback among research and development projects in the agroforestry sector
- Legally protect highly threatened natural resources near farming zones

(Asare, 2006, Beer et al. 2003)

3.2.1 Biodiversity loss

All forests are affected on some level by direct and indirect human activity, although there are no accurate global assessments of forest conditions (Schroth et al., 2004). At the end of the last millennium, Oldfield et al. (1998) estimated that around 10 % of the world's 60,000–100,000 tree species were threatened with extinction. Which is usually caused by inconsiderate logging. Between 1990 and 2000, 14.2 million ha per year of tropical forest were deforested, with an additional 1 million ha per year converted to forest plantations. Natural forest expansion over this time was 1 million ha per year, with an additional 0.9 million ha per year afforested by humans as forest plantations. This deforestation occurred differently on regional and local scales. For instance, during this 10-year time period, the country of Burundi in Central Africa lost 9 percent of its remaining forest per year (FAO 2001).

The most harmful influences for forrest, which is also connected with biodiversity are unchecked clearing, burning, fragmentation of forest, degraded land by agricultural expansion, mining and timber extraction. Given that forest ecosystem disturbances diminish biodiversity by displacing or replacing natural habitats there is the need to balance the economically driven agricultural expansion with strategies relevant for conserving natural resources, and maintaining ecosystem integrity and species viability (Asare, 2006).

Diminishing of biodiversity is well showed in Table 6 (Appendix).

3.2.2 Deforestration of Asia

Southeast Asia has the highest relative rate of deforestation of any major tropical region. Natural habitats, such as lowland rain forests, are being destroyed at relative rates that are higher than those of other tropical regions and could lose three quarters of its original forests, resulting in massive species declines and extinctions, which means up to 42% of its biodiversity by the turn next century (Achard et al., 2002). More importantly, this biodiversity crisis is likely to develop into a full-fledged disaster, as the region is home to one of the highest concentrations of endemic species (Myers et al., 2000).

Figure 3 shows how high level of biodiversity in endangered by deforestration in tropical Asia.

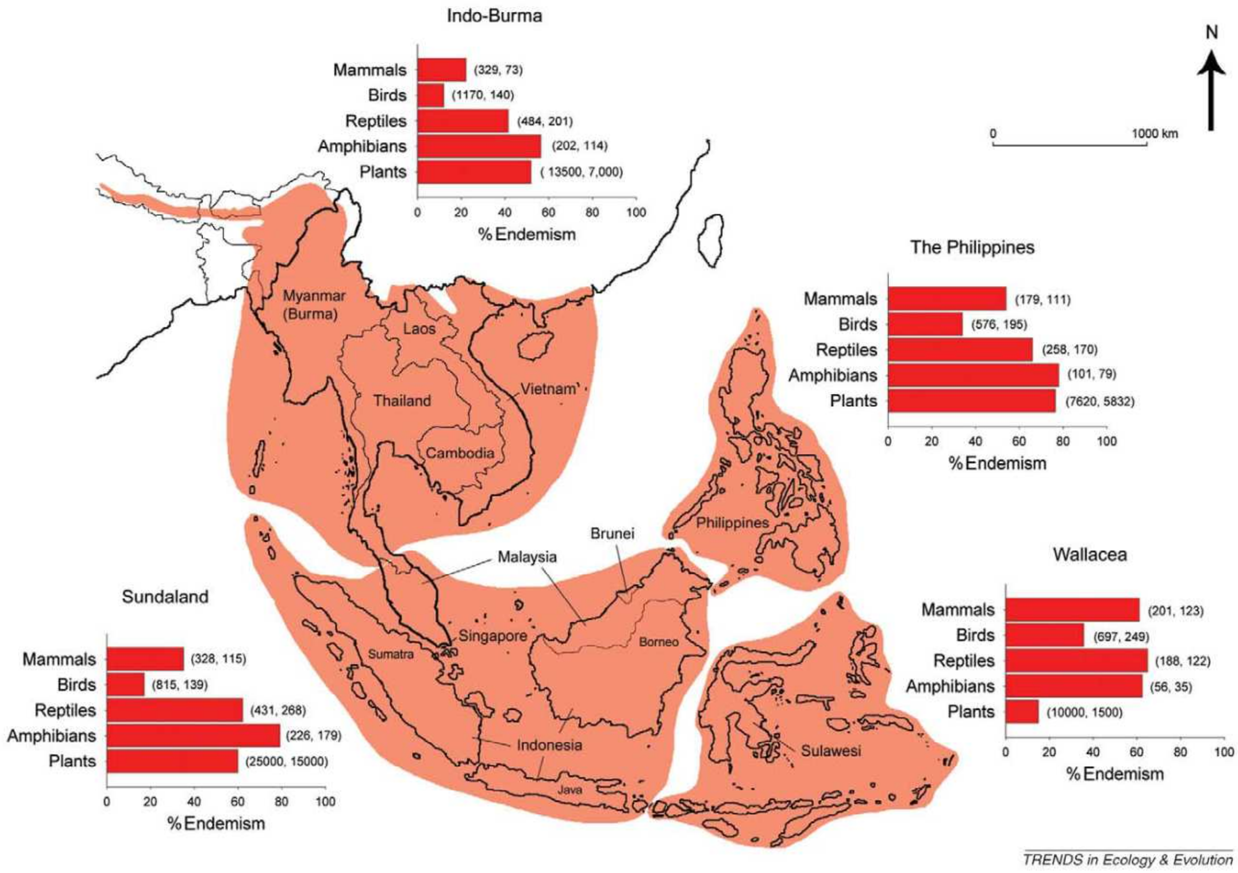

Figure 3. Species richness and endemism in Southeast Asia. (Sodhi et al., 2004)

3.2.3 Diversity of trees

3.2.3.1 Shade trees

Shade trees can also be maintained for various benefits to the agroecosystem. Leguminous tree species (Erythrina spp, Gliricidia spp and Inga edulis) are widely used for their nitrogen fixation from atmospheric nitrogen. In Indonesia, Erythrina and Gliricidia trees reportedly resulted in a N-fertilization of soils of up to 69 kg/ha/year (Anhar, 2005). In Perú, shade trees were even successfully used for the rehabilitation of cacao agroforests where production stagnated after soil depletion (Kraus and Soberanis, 2001). In addition, shade tree stands in cacao agroforests have been related to lower pest pressures (Beer et. al.,1998), high carbon storage and sequestration (Verchot et. al.,2007), microclimate stabilization (Sporn et. al.,2009) and soil protection against heavy rainfall (Dietz et. al.,2006). Alarmingly, shade tree removal is currently inherent to cocoa production cycles. The removal of shade when plantations become productive is predicted to increase productivity in the short term and leads to increasingly dominant zero-shade cacao monocultures in all major cocoa producing regions. In the long term, however, shade removal is a recognized threat to the productivity of cacao plantations and is arguably one of the main causal factors underlying the cut-and-run cycles of cacao booms and busts (Ruf and Schroth, 2004).

The shade tree shelter on the cacao/multi-species forestry was composed of *Erythrina* sp, *Durio zibethinus*, *Leucaena leucocephala* , *Aleurites moluccana* and *Annona muricata*; also few *Gliricidia sepium* and bananas (*Musa* sp.) occurred (Köhler et.al., 2013).

3.2.3.2 Fruit trees

The indigenous farming systems of many development countries often include several fruit- and nut-producing trees. These are common components in most homegardens and other mixed agroforestry systems; they are also integrated with arable crops either in intercropping mixtures or along boundaries of agricultural fields. These fruit trees are well adapted to local conditions and are extremely important to the diet, and sometimes even the economy, of the people of the region, but they are seldom known outside their common places of cultivation (Nair, 1993).

3.2.4 Diversity of terrestrial herbs

In cacao agroforestry systems, herbaceous vegetation mostly consists of weeds and weeding is a common practice by cacao farmers. Multi-taxa comparisons of flora and fauna revealed no relation of the herb layer vegetation to overall diversity or species composition of other groups (Clough et. al.,2009; Kessler et. al.,2009), except for conservation of native amphibians and reptiles in the leaf litter layer (Wanger et. al., 2009). Ramadhanil et. al., (2008) compared the herb layer of shaded cacao agroforestry systems with that of forest sites in Indonesia. Herb species richness in the cacao agroforestry systems was about three times as high in cacao agroforests (35 species per 40 m_2) than in the nearby undisturbed rainforest sites, most likely due to the thinner canopy cover that allows more sunlight to reach lower vegetation layers. Interestingly, cacao agroforests with shade tree stands that remained from previous forest cover had herb layers that showed most similarity with that of the rainforest sites. Species composition changed drastically from plant communities dominated by various families in the forest sites to communities predominantly consisting of Asteraceae, Poaceae and several invasive species in the cacao agroforestry systems with planted shade trees.

3.2.5 Diversity of mammals

Protected mammal species are often considered “flagship species” of which the presence is a conservation priority. Based on animal tracks, Harvey *et. al.,* (2005) found that mammal abundance in cacao agroforests can remain as high as in rainforests. However, species richness did decline in agroforests, most likely due to a combination of lacking food resources and higher hunting pressures. The latter may in part can be an effect from farmers’ suspicion that mammals, such as monkeys and rats, are primary cacao pests (Arlet and Molleman, 2010).

Cacao agroforests can harbor significant mammal populations, which has been illustrated by Muñoz *et. al.,* (2006) who studied a group of howler monkeys (*Alouatta palliata*) in a Mexican cacao plantation. For decades, these monkeys lived solely from 16 out of 32 shade tree species in the 8 ha plantation. Their presence was not associated with reduced productivity of the cacao trees as the monkeys primarily fed on shade tree foliage. Similarly, Cassano *et. al.,* 2011 reported the Brazilian “cabrucas” as a preferred habitat of the endangered maned sloth (*Bradypus torquatus*), primarily due to the diverse and dense shade tree stands that included forest tree species.

The protection of single “flagship” mammal species necessitates the conservation of other important biodiversity for resources and shelter. For example, Vaughan *et. al.,* (2007) identified over 100 tree species that were used by only two protected sloth species in Costa Rican cacao agroforests, indicating that in order to preserve these two species, a high amount and diversity of trees has to be maintained as well, which in turn may provide habitat to high numbers of other species.

Only few mammal groups inhabiting cacao agroforests, such as bats and other small mammals, have high enough numbers of species to be included in biodiversity research on this type of landuse. Therefore, mammalian biodiversity research in cacao agroforests has concentrated on these animal groups. In cacao agroforests on the island of Sulawesi, Indonesia, Weist *et. al.,* (2009) recorded eight species of rats, four of which were endemic to Sulawesi. Interestingly, the native rat species tended to decline with increasing forest distance, whereas occurrence of introduced species was not related to forest distance. In a selection of Brazilian “cabruca” cacao agroforests, Faria *et. al.,* (2006) observed 44 species of bats, with richness declining with fragmentation of the forest-agroforest mosaic.

Because mammals in cacao agroforests (particularly rodents) can consume fruits of the cacao tree as well, some native and even endemic species are considered as cacao pests (Entwistle, 1972; Bhat *et. al.,* 1981). Conversely, mammals that primarily feed on the leaves of shade trees can be beneficiary to the agroecosystem in their “pruning” effect on the shade cover and the soil fertilizing effects of their excrements (Muñoz *et. al.,* 2006).

Clough et.al. (2010) shows biodiversity stances of mammalian fauna in Sulawesi. Which consist mainly bats (Microchiroptera) and rats (Muridae). It is not particularly rich in species but shows a very high level of endemism. There are 127 mammal species, 79 of which are endemic. Endemism rises from 62 to 98 % if bats are excluded (Whitten et al. 2002), and most of these species are rats. In spite of the high level of endemism and the endangered natural habitats in Sulawesi, not much is known about the ecology of the murids and how they react to intensification of agroforestry and landscape fragmentation as existing studies focus mainly on taxonomic relationships (Musser 1991, Musser and Dagosto 1987). There are but a few studies on small mammals and their ability to use agroforests as potential habitat. These studies were mainly conducted in South America (Estrada et al. 1994) and India (Bali et al. 2007) and showed that mammals can use cacao agroforests as a potential habitat, but are less diverse in plantations than in forests and more frequently found in agroforest systems that are closer to the forest. Even in diverse agroforests, forest specialists are often missing because they need the native forest for a certain period of their life (Rice and Greenberg 2000).

Studies on small mammals e.g. from Borneo (Wells et al. 2007) or Venezuela (Ochoa 2000) showed that especially rare and specialised species are most likely to be affected by habitat change. This effect leads to a reduction of diversity even if losses in species richness are covered by an increasing number of individuals from species which are tolerant to disturbance (Cottingham et al. 2001, Ernest & Brown 2001)

3.2.6 Diversity of insects

In the Amazon, there are about 50,000 species of insects , but the actual number , including estimated non - described species may be much higher. Insects are an important group for the local ecosystem. Many species (not only endemic) are specialists , depending on the specific abiotic and biotic habitat characteristics, such as low light intensity, specialty food plants, etc. Therefore, they react very sensitively to environmental disturbances. Habitat properties, such as vegetation and structure of plant communities, changes in the course of succession, which affects insect communities (Southwood et al . , 1979). Each group has its position and role in the ecosystem and representatives are well adapted to the environment. According to the specific arrangements, there is developed a strong interaction between insects and rainforest. Closely related species are more sensitive to forest disturbation often undergo a transformation. Deforestation not only changes the vegetation cover, but also the structure of biological diversity and the causes of biodiversity loss (Table 4) (Lojka et al., 2010).

In comparison with other forms of land-use, such as annual crops and oil palm plantations, richness of cacao agroforestry systems is high (Bos *et. al.,* 2006) and can be comparable with that of rainforests (Bos *et. al.,* 2007). High numbers of insect species feed on cacao trees, but their most important natural enemies are insects as well (Entwistle, 1972) and they are an important food resource for animals higher up the foodweb (Van Bael *et. al.,* 2007). Cacao is pollinated by tiny midges (Entwistle, 1972) and also intercropped fruit crops are primarily pollinated by insects that naturally occur in the agroecosystem or its surroundings (Hoehn *et. al.,* 2008)

Table 5 Incidence (in %) of insect orders in different land use systems

	YSF	AFS-A	AFS-B	MC	WL	WH
Ensifera	4.09	8.20	6.11	20.40	23.50	37.70
Caelifera	26.60	6.70	20.00	26.70	6.70	13.30
Homoptera	17.50	7.21	6.19	25.80	14.40	28.90
Heteroptera	11.21	18.90	18.90	13.19	18.90	18.90
Hymenoptera	24.00	14.00	8.00	16.00	22.00	16.00
Hymenoptera - ants	24.80	30.40	18.90	10.30	6.96	8.64
Diptera	18.03	27.02	14.81	6.54	6.54	27.06
Coleoptera	30.50	9.27	26.50	13.90	8.61	11.22
Odonata	87.50	0.00	12.50	0.00	0.00	0.00
Mantodea	100.00	0.00	0.00	0.00	0.00	0.00
Thysanoptera	57.20	21.40	21.40	0.00	0.00	0.00
Blattodea	50.00	0.00	0.00	25.00	0.00	25.00
Neuroptera	100.00	0.00	0.00	0.00	0.00	0.00
Grilloidea	0.00	0.00	0.00	50.00	25.00	25.00

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

3.2.6.1 Ants

One of the most significant and most abundant insect families is the ant family (*Formicidae*). Ants are overspread worldwide and have adapted to different conditions and vegetation structure. Ants represent a significant family of the Hymenoptera order. There are about 15,000 species of ants living on the Earth (Hölldobler & Wilson 1990). Representatives of this family are overspread worldwide, but the Neotropical and African areas have the greatest number of endemic genera (Bolton 1994). Ants live in numerous, well-organized colonies and are territorially very frequent. Ants form a very important taxon in the Amazon Basin. For example, one-third of the entire animal biomass of the Amazonia *terra firma* rain forest is composed of ants and termites: on one hectare of soil more than of 8 million ants and 1 million termites live (Hölldobler and Wilson 1990). Ants are essential components of ecosystems not only because they constitute a great part of the animal biomass but also because they act as ecosystem engineers. Ants play one of the main roles in invertebrate biodiversity also in agriculture land use systems. The highest ant biodiversity is described in the natural and secondary forest but also agroforestry systems provide good conditions for the ant occurrence. There are two main groups of ants in the ecosystem: the soil ants and the canopy ants. Soil ants may belong to the different trophic levels ants as primary consumers; predators and melivores as secondary consumers), all can be classified as ecosystem engineers (Jones et al. 1994). Ants also improve the soil conditions. Construction of ant nests changes the physical and chemical properties of the soil increasing its drainage and aeration by the formation of underground galleries, and transforming organic matter and incorporation nutrients by food storage, aphid cultivation, and the accumulation of faeces and corpses (Brian 1978).

In fact, two ant species have a high potential for the biological control of cocoa pests in Bahia, thereby exerting a positive influence on cocoa production. *Azteca chartifex spiriti* Forel (Dolichoderinae; Dolichoderini) and *Ectatomma tuberculatum* Olivier (Ectatomminae; Ectatommini) can protect the cocoa plants from thrips *Selenothrips rubrocinctus* (Giard) (Thysanoptera; Thripidae) and mirids (Hemiptera) [*A. chartifex spiriti*], while the principal prey of *E. tuberculatum* are chrysomelid beetles, leaf-cutter ants, and caterpillars (Delabie 1990). The positive influences of these and other ant species greatly benefit cocoa production.(Ruf et al. 1994)

3.2.6.2 Pollinators

Over the past decade, the importance of pollinators as a key element of biodiverzity supporting human livelihoods has been increasingly recognised in temperate and tropical regions. This is not surprising as most plants bendit from pollinators, encompassing organisms as contrasting as bees, flies, birds, bats and other mammals. For example, 90% of Angiosperms in tropical rainforests are now estimated to rely on animal pollination (Bawa 1990)

The proportion and configuration of natural habitats in agricultural landscape matrices seem to be the major land-use variables promoting pollinator diversity and consequently the mutualistic interactions associated with the services pollinators deliver to plants (Brosi et al. 2008, Ricketts et al. 2008) The functional consequence of plant-pollinator interactions associated with natural habitat might then entail human benefits such as horticultural, wild plant species, and genetic diversity. In reality humans are still eliminating natural habitats despite their ecological importance. (Clough et.al., 2010)

3.2.7 Diversity of avian

Dense and diverse shade tree stands in cacao agroforests can harbor high bird species richness. Particularly canopy roaming and frugivorous species can very well cope with cacao agroforests. In a survey by van Bael *et. al.,* (2007) in Panamá, densely shaded cacao agroforests harbored 188 bird species, whereas in the same survey only 148 species were recorded in nearby forest sites. This is in support of results from the Brazilian "cabruca" cacao plantations, where the dense and diverse shade tree stands harbored more birds and bird species than the canopies of nearby natural forest sites (Faria *et. al.,* 2006).

Estrada and Coates-Estrada (2005) compared agroforestry systems (including dense shade cacao agroforests) with forests and zero-shade pastures and found that agroforestry systems indeed preserve levels of species richness that resemble and even exceed that of natural forests, but that species richness declines drastically in other, less shaded forms of agriculture. This key-role of shade trees in the conservation of tropical birds has also been shown on the island of Sulawesi, Indonesia, where bird species richness declined with 80% from forests to cacao agroforests with few planted leguminous trees (Waltert *et. al.,* 2004).

Nevertheless, transition from forest to cacao agroforests does result in changes in species composition. In Panamá, the transition was particularly caused by a decline of understory bird species and favored migratory bird species (van Bael *et. al.,* 2007). In Brazil, the transition caused a shift in bird species assemblages from habitat specialists to habitat generalists (Faria *et. al.,* 2006), which have lower priority from a conservation point of view. Similarly, Clough *et. al.,* (2009) showed a decline in forest specialists in response to increasing distance from forests on Sulawesi. In that study, granivorous bird species were the only group that increased in abundance and richness in cacao agroforests that were more isolated from natural forest sites.

Most bird species in cacao agroforests are insectivores and frugivores (Waltert *et. al.,* 2004, Faria *et. al.,* 2006; Clough *et. al.,* 2009) but there are no known records of birds feeding on cacao itself. In cacao agroforests, birds have even been linked to lower densities of herbivorous invertebrates on cacao trees and were therefore accredited pest reducing properties (van Bael *et. al.,* 2007).

Reitsma et al. (2001) surprisingly showed in their study that cocoa plantations does not always reduce the biodiversity. In total of 1464, 1713, and 1708 individual birds and 130, 131, and 144 total species were detected in forest, abandoned cacao, and managed cacao respectively over the two sampling periods. No season effect on bird abundance and diversity existed within habitats. Abandoned and managed cacao had significantly more individual birds per point than forest, and managed cacao had significantly more species per point than the other habitats. Habitat affinity analyses showed, however, that forest specialists were significantly less represented in the cacao habitats compared to forest. Managed cacao, had significantly more agricultural generalist individuals than both the abandoned cacao and forest patches.

3.2.8 Diversity of Reptiles and Amphibians

Only few biodiversity studies have been carried out in cacao agroforests that included amphibians and reptiles, despite the endangered status of particularly amphibian species (Stuart *et. al.,* 2004). For example, after 35 years of observations, Whitfield *et. al.,* (2007) reported a 75% decline of leaf-litter dwelling amphibians and reptiles in Costa Rican rainforests.

Parallel to the sharp declines in Costa Rican rainforests, Whitfield *et. al.,* (2007) reported a remarkably constant richness and even a slight increase of amphibians and reptiles in nearby abandoned cacao plantations. Although these plantations were abandoned for at least two decades, the contrasting trends could be explained by the fact that cacao trees have several leaf flushing events each year, contributing to a greater leaf litter accumulation while litter accumulation in the natural forest sites decreased, possibly due to effects of climate change (Whitfield *et. al.,* 2007).

Other factors that stimulate the herpetofauna in cacao agroforestry systems are the presence of branch piles, a thick cover of shrubs (Wanger *et. al.,* 2009) as well as ponds and streamlets, and food resources as lepidopteran larvae, beetles and spiders (Solé *et. al.,* 2009).

In their comprehensive field observations on the island of Sulawesi, Indonesia, Wanger *et. al.,* (2009) recorded six amphibian and 17 reptile species in 43 plantations. Habitat variation is required to accommodate the different life histories of the herpetofauna, hence they stressed the importance of a landscape level, integrative management approach with maintenance of thick leaf litter layers, dense shrub cover and branch piles in cacao agroforestry systems. For the conservation of native forest herpetofauna, the presence of nearby forest sites is of key importance. Faria *et. al.,* (2007) reported high proportions of native forest lizards and frogs in the Brazilian “cabruca” cacao agroforests, but the amount of forest species declined in landscapes where such “cabrucas” dominated above rainforests.

4. Results and Discussion

Cocoa agroforestry systems can make a significant contribution to biodiversity conservation at both the plot and landscape scales by providing habitat and resources to a wide range of plant and animal species. However, not all forest species are able to use cocoa agroforests as habitat, and cocoa agroforests appear to host more forest species if they are situated in landscapes with high forest cover, suggesting that forests serve as important source areas for species in agroforestry landscapes. Furthermore, agroforests are often subject to processes that reduce their habitat value, ranging from the replacement of native forest trees with planted fruit trees (often including exotic species) to the outright conversion to other land uses. It is thus clear that relying on cocoa agroforests alone for the conservation of forest biodiversity would be ineffective for some species and risky for many others. The conservation of biodiversity in cocoa production landscapes requires the conservation of sufficient areas of natural habitat, but can benefit greatly from the additional habitat that complex cocoa agroforests can provide (Schroth & Harvey, 2007).

How can we determine if cocoa cultivation can be sustained without harming ecosystems?

Different models of cocoa cultivation will be more or less sustainable depending on their regional ecological and socio-economic context. The factors impacting sustainability are best understood when we consider actual situations rather than theoretical ones. However the literature does conclude that shaded cocoa has a more positive environmental impact than sun cocoa and can be the most sustainable and cost-effective of all models when the farm is an agroforest generating stable and diversified income for the farm family (Daniels, 2006).

Cocoa growing in full sun, is likely to be unsustainable in the long term and increases the risk of crop failure due to drought , reduces the level of nutrients in the soil, and increase insect and disease infestation. Full-sun cacao cultivation simplifies the forest environment, increases habitat fragmentation, and isolates basic protected forest areas from adjacent forest lands (Belsky and Siebert, 2003). Cocoa growing in full sun is labor intensive and longevity of such system is shorter. The development of cacao trees is faster, unlike, in accordance with Isaac et al. (2007), the biomass growth is generaly lower.

Replanting of these systems is relatively difficult. The yield of sun-grown cocoa is higher, but the need for fertilizer and insecticide increases (Johns, 1999).

One of the really important agroforest woody plant is *Inga edulis* (Fabaceae family), which providing sweet edible pulp of the pods. Duke (1983) also noted that wood from I. edulis can be used for boxes, crates, furniture, general carpentry and light construction, but farmers do not grow *Inga* for this purpose. I. edulis is also very valuable for ability to improve cocoa agroforestry by conserve of organic matter and fixing of nitrogen.

The biodiversity value of traditional shade-grown coffee and cacao farms is due to the high canopy tree species diversity, multilayered forest structure, and the presence of lianas and epiphytes. Shaded farms also exhibited low levels of exotic weeds in terms of both the number of species and percent ground cover. The presence of weed species is a useful proxy for disturbance (Gascon et al. 2000) and an indicator of the extent to which native floristic diversity has been retained in the wake of exotic species invasions. The floristic and structural diversity of shade-grown coffee and cacao farms provides habitat for native fauna, as is evident by the observed diversity of bird guilds and species. Local farmers also reported that small mammals, deer, wild pigs, macaques and other forest fauna are regularly observed and occasionally hunted in these farms. In contrast, no birds were observed in the full-sun farm and forest animals were reported to be rare in these sites, even where adjacent to shade farms and remnant primary forest patches

A diversity of vegetation types and structure also modifies microclimatic conditions, thereby providing a wide range of niches for other plant, animal and insect communities. In addition, flora and fauna may interact to maintain and even enhance biological diversity. For example, birds and bats are known to be important dispersers of pioneer and primary forest tree, shrub, herb and epiphyte species (Galindo-Gonzales et al. 2000). Structurally diverse forest farms that provide sites for birds and bats to feed and perch may enhance seed dispersal and establishment of woody vegetation. They may also provide connectivity between isolated primary forest fragments (Galindo-Gonzales et al. 2000)

The widespread transformation of traditional to complex forest farming systems grown monocultures of cacao may adversely affect long-term agricultural productivity, simplify forest environments, increase habitat fragmentation, lead to exotic weed species invasions, and isolate primary forest in protected areas and remnant fragments. In contrast, shade-grown perennial farms provide valuace economic and biodiversity conservation benefits and appear to have been productive for decades. The future of biodiversity in the tropics will depend largely upon what occurs on agricultural and forestlands outside of protected areas (Janzen 1998). Agricultural development and forest conservation efforts should seek to maintain and enhance traditional shade-grown forest farming systems on matrix lands, as these practices are integral to local livelihood strategies and komplement biodiversity conservation objectives (Lenne and Wood 1999).

5. Conclusion

Theobroma cacao is originally undergrown tree. When the cocoa trees are grown under shade the occurrence of pests and diseases is significantly decreased, but there is higher occurrence of molds due to low air flow and very high humidity.

In study we can see many different types of cocoa growing but only growing in full-sun conditions is much more unsustainable and harmful for environment than others.

Mostly due to high usage of pesticides and fertilizers which affect species composition of plants and animals, but also can cause higher salinity of soil a PH after soil losing its fertility.

With the general decline in forest cover over the last few years, and the increasing threat from illegal logging of trees for timber, there is an urgent need for artificial regeneration of forest cover. Judging from the good initial growth performance of some of the planted species, it is recommended that active planting of cocoa shade trees, using indigenous forest tree species for saving local original biodiversity structure.

Potencial of cocoa agroforestry for biodiversity conservation is quite high. Which make agroforestry sustainable, but when we consider the amount of deforestred area (10 million ha) of tropical zones because of agroforestry, it start to be damaging. Cocoa agroforestry can conserve biodiversity, but it cannot be same in species richness as primary forest.

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Appendix

Table 6 Influence of cacao farming systems on species presence of plant and animal groups.

Species group	Natural forest (NF)	Secondary forest (SF)	Cacao agroforests (CA)	Full sun plantations (FP)
Trees	50-60 sp. per 0.25 ha	Similar diversity to NF, but composition differs	Intermediate diversity	Few species, many non- native
Rattan	Heavily exploited	Heavily exploited	Little or none	None
Lianas	6-12 sp. per 0.2 ha	Similar to NF	Similar to NF, but smaller, more herbaceous species	Species poor (0-5 sp. per 0.2 ha)
Herbs	Very high species richness (171-204 sp.), low density		High diversity (176 sp.), high density species	Density high if no herbicide use, many pantropic species, few shared with forest
Bryophytes	High local diversity (150 sp. on eight mature trees)		Loss of 70% of the NF species	Very species poor, removal by farmers
Ants	High diversity		Similar diversity as NF (163 sp. found), 75 % forest species retained, but endangered by invasive species	Few species lost, additional non-forest species, but endangered by invasive species
Bees	Few solitary sp. with low density, many, abundant social species		Increase of solitary species diversity and density, fewer social bees	Decrease of solitary species diversity compared to CA, fewer social bees
Dung beetles	17 species, 25% of species only at forest sites		Similar to NF, slightly different composition	
Fruit-feeding butterflies	Highest diversity, most endemic species	Diversity reduced by one third (older secondary forest)	Relatively high diversity (35 sp.)	Several species more abundant in less-shaded cacao
Birds	High species richness, especially endemics (altogether 224 sp. known in Sulawesi)		Increase in habitat generalists, fewer endemics and NF specialists	More granivore species, less insectivores, few endemics and NF specialists