DEPARTMENT OF BIOLOGY AND
ENVIRONMENTAL SCIENCES

AGROFORESTRY AS A BIODIVERSITY CONSERVATION TOOL AND THE MOTIVATIONS AND LIMITATIONS FOR SMALL SCALE FARMERS TO IMPLEMENT AGROFOREST SYSTEMS IN THE NORTH-EASTERN ATLANTIC FOREST BIOME IN BRAZIL

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Summary

This research investigates the biodiversity conservation value of agroforest systems and the motivations and limitations for small scale farmers to implement these systems in the north-eastern Atlantic Forest biome. This thesis aims at answering these research questions:

1. To what extent can agroforestry systems in southern Bahia provide habitat for three emblematic endemic species of the Atlantic Forest (from a landscape and farm scale perspective)? Emblematic species: golden-headed lion tamarin (*Leontopithecus chrysomelas*), maned sloth (*Bradypus torquatus*), and golden-bellied capuchin (*Sapajus xanthosternos*)
2. To what extent is agroforestry a viable option for small scale farmers in the Bahia sub-region of the Atlantic Forest?
3. What barriers exist for small scale famers and how could these be overcome to increase farmer's willingness for agroforestry?

For researching the potential of agroforest systems to serve as habitat for the analyzed species a comprehensive literature review was done. Additionally, to investigate the three research questions, questionnaires were sent to farmers working with agroforestry and conventional agriculture. The literature review indicated that the following factors were the most important for determining if agroforest systems were used by any of the three analyzed species: hunting pressure, presence of dogs, canopy connectivity, occurrence of plants that make up the species diet, and proximity to forest remnants. The questionnaires showed that the three main reasons why farmers worked with agroforestry were: a higher income generation (89%), the diversification of the production system (86%), and an increase in the land's quality and productivity (86%). Moreover, the three most common mentioned limitations for conventional agriculture farmers to shift to agroforestry practices were: uncertainty if the system will work (62%), reduction in yield of the main agricultural crop (43%), and a lack of models and knowledge in the region (41%). This research concludes that increasing the technical assistance, rural extension, and capacitation/training in agroforestry practices are the most important factors for increasing farmers willingness for agroforestry in the studied region, since these can reduce the uncertainty and increase the occurrence of successful models and knowledge related to agroforestry in the region.

<u>Resumo da pesquisa</u> (Summary in Portuguese)

Esta pesquisa investiga o valor de conservação da biodiversidade dos sistemas agroflorestais (SAF) e as motivações e limitações para que agricultores familiares possam criar SAF no nordeste da Mata Atlântica. Este artigo visa responder às seguintes perguntas:

1. Até que ponto podem os SAFs no sul da Bahia servir como hábitat para: o mico-leão-de-cara-dourada (*Leontopithecus chrysomelas*), a preguiça-de-coleira (*Bradypus torquatus*), e o macaco-prego-do-peito-amarelo (*Sapajus xanthosternos*)?
2. Até que ponto são os SAF uma opção viável para os agricultores familiares da sub-região da Bahia na Mata Atlântica?
3. Quais são as limitações principais para os agricultores familiares e como podem ser superadas para incentivar o agricultor a implementar SAF?

Para pesquisar o potencial dos SAF para servir de habitat para as três espécies analisadas eu realizei uma busca bibliográfica utilizando palavras-chave pré-definidas nos websites de *Web of Science* e *Scopus*. Além disso, para responder às três perguntas da pesquisa eu enviei questionários para agricultores familiares que trabalham com SAF e com "agricultura convencional". A busca bibliográfica indicou que os seguintes fatores foram os mais importantes para determinar se os SAF foram utilizados pelas três espécies analisadas: a pressão da caça, a presença de cães, a conectividade do dossel florestal, a ocorrência de plantas que compõem a dieta dás espécies, e a proximidade aos remanescentes florestais. Os questionários mostraram que as três razões principais pelas quais os agricultores trabalharam com SAF são: uma maior geração da renda (89%), a diversificação da produção (86%) e o aumento na qualidade e produtividade da terra (86%). Os fatores limitantes mais comuns para a migração para práticas agroflorestais mencionadas pelos agricultores que trabalham com "agricultura convencional" são: a incerteza se o sistema funcionará (62%), a redução na produção do cultivo/gado principal (43%), e a falta de modelos exitosos e conhecimento de SAF na região (41%). Esta pesquisa concluiu que o aumento da assistência técnica, extensão rural e capacitação/treinamento em práticas agroflorestais é o fator mais importante para incentivar os agricultores familiares a implementar SAF na região estudada, pois isto reduziria a incerteza e aumentaria a presença de modelos exitosos e o conhecimento relacionados aos SAF na região.

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Abstract

Research related to the field application of agroforestry practices and socio-economic factors related to it are still scarce. This research investigated the potential of agroforests for serving as habitat for the golden-headed lion tamarin (*Leontopithecus chrysomelas*), the maned sloth (*Bradypus torquatus*) and the golden-bellied capuchin (*Sapajus xanthosternos*) in Brazil´s north-eastern Atlantic Forest biome. More importantly, this research focused on investigating the motivations and limitations for small scale farmers to implement agroforest systems in the mentioned region. To investigate these aspects a comprehensive literature review was done, and additionally, questionnaires were sent to farmers working with agroforestry and "conventional agriculture". The following factors were the most important for determining if agroforest systems benefited any of the three analyzed species: hunting pressure, presence of dogs, canopy connectivity, occurrence of plants that make up the species diet, and proximity to forest remnants. The three main reasons why farmers worked with agroforestry were: a higher income generation (89%), the diversification of the production system (86%), and an increase in the land's quality and productivity (86%). The three most common mentioned reasons for conventional agriculture farmers to not shift to agroforestry practices were: uncertainty if the system will work (62%), reduction in yield of the main agricultural crop (43%), and a lack of models and knowledge in the region (41%). This research concludes that increasing the technical assistance, rural extension, and capacitation/training in agroforestry practices are the most important factors for increasing farmers willingness for agroforestry in the studied region.

Figures

Abbreviations

GHLT – Golden-headed-lion tamarin

GBC – Golden bellied capuchin

Bahia SR – Bahia sub-region

INCAPER – Instituto Capixaba de Pesquisa, Assistência Técnica e Extensão Rural

PES – Payment for ecosystem services

Introduction

Agroforestry for biodiversity conservation and agricultural production

Agroforestry or agroecology is a term used to define land-use systems that combine agricultural and silvicultural practices to produce food, wood, and other products. Agroforest systems are defined in different ways by research (Atangana et al. 2014; Ramachandran 1993). The definition used in this paper is based on the commonly used definition of the World Agroforestry Centre (ICRAF) (Ramachandran 1993):

"Agroforestry is a collective name for land-use systems and technologies where woody perennials (trees, shrubs, palms, bamboos, etc.) are deliberately used on the same land-management units as agricultural crops and/or animals, in some form of spatial arrangement or temporal sequence."

Agroforest systems have been increasingly promoted as land-use systems that can support nature conservation, especially in the tropics (Ramachandran 1993; Atangana et al. 2014; Beenhouwer et al. 2013). Agroforestry in the tropics has also been gaining recognition as a tool for reducing poverty, improving food self-sufficiency for farmers, and increasing the productivity and income for small scale farmers (Atangana et al. 2014; Ramachandran 1993; Leakey 2014). Even if agroforestry systems have a great potential for more sustainable use of natural resources and land, and can improve the livelihood of small scale farmers in the tropics, it is important to point out that this is not a "silver-bullet" or a "one-size-fits-all" approach for reconciling nature conservation and agricultural production (Atangana et al. 2014; Ramachandran 1993).

If agroforest systems are going to be used as part of a strategy for biodiversity conservation, it is necessary to identify the characteristics that will make these systems suitable for supporting its local biodiversity. The two main areas that influence on the biodiversity conservation value of agroforests are: the species and structural composition of agroforests (Rolim & Chiarello 2003) and the degree of the management intensity and human disturbance in these systems (Cassano et al. 2014). It is important to point out that agroforest systems cannot simply replace the biodiversity value and ecosystems services provided by natural forests, but if agroforests contain similar species and structural composition as native forests and they are not intensively managed they can be used as part of a broader regional biodiversity conservation strategy, and potentially serve as buffer zones or ecological corridors (Cassano et al. 2014).

Agroforest systems have the potential to improve the livelihood of small scale farmers and alleviate poverty, but there are certain limiting factors as well. Small scale farmers are defined in this paper according to how "family farmers" are defined in the Brazilian Atlantic Forest Law (Presidência da República 2006), which is:

"*Farmers that own a farm not bigger than 50 hectares, and work their farms with their own personal work and with the work of their family, with the eventual help of third parties, (also collectives where the area of the land per person is not bigger than 50 hectares), and at least 80% of the gross income of the farm has to come from activities related to agriculture, livestock or silviculture or from rural extractivism."*

Some of the potential benefits for small scale farmers in using agroforest systems are the increase in the land´s quality and productivity (Leakey 2014), food security (Kang & Akinnifesi 2000), the diversification of the produced goods (Ramachandran 1993), and the increase in resilience towards biological diseases, market impairs and climate change (Atangana et al. 2014). On the other side, some of the most relevant limitations for small scale farmers when working with agroforestry are the challenge of managing woody perennials and agricultural crops in the same land management unit (Atangana et al. 2014), the difficult marketability of some products (Ramachandran 1993), and other legal aspects such as the environmental protection of certain trees or licenses needed for cutting down woody perennials (Porro & Miccolis 2011). Another disadvantage of working with agroforest systems is that initially it takes a long time for the trees and woody perennials to produce goods and it prolongs the time of getting returns from the investment done in these type of plant species (Rolim & Chiarello A.G. 2003). Also, in many countries (especially in countries like Brazil, where the legislation is often not being enforced) there is an uncertainty regarding ownership of land, meaning that that the land ownership is not guaranteed. All these limitations and disadvantages can lead to farmers investing more in crops that generate returns in the short-term instead of systems that generate higher financial returns in the long term (Ramachandran 1993; Porro & Miccolis 2011).

The Atlantic Forest

Biodiversity loss is one of the biggest environmental threats faced nowadays, and the tropical zone has the highest and most threatened biodiversity value in the world (Myers et al. 2000). The Atlantic Forest is one of the 25 biodiversity hotspots in the world (*Figure 1*), these "hotspots" are defined as deeply threatened regions with high levels of biodiversity and endemism (Myers et al. 2000). Moreover it is considered as one of the most endangered forests in the world (Mittermeier et al. 2005) and one of three most vulnerable biodiversity hotspots to climate change (Bellard et al. 2014).

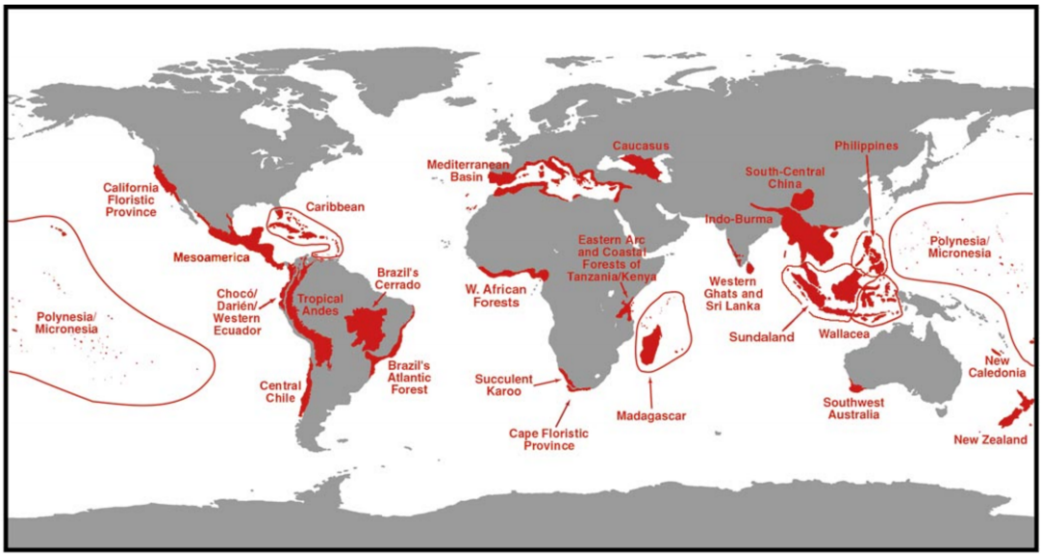


Figure 1. *The world´s 25 biodiversity hotspots. The hotspot expanses comprise 30-3% of the red areas. (Source: Myers et al. 2000).*

The Atlantic Forest is the second largest rainforest in South America, originally covering around 150 million hectares (ha) along the coast of Brazil and into eastern Paraguay and the northeast of Argentina (*Figure 2*) (Ribeiro et al. 2011). The Atlantic Forest is very heterogenous and it is composed by different types of vegetation. The evergreen to semideciduous forests cover the greater part of the Atlantic Forest, but there are also many other forest types such as deciduous forests, *restingas* (coastal forest and scrub on sandy soils), mixed *Araucaria* pine forests, swamps and mangroves (Ribeiro et al. 2011). This diversified forest mosaic encompass more than 20 000 plant species, 263 mammals, 936 birds, 306 reptiles, 475 amphibians, and many more species that still lack scientific description (Mittermeier et al. 2005).

The Atlantic Forest has been suffering a continuous habitat loss since the arrival of the European colonists in the sixteenth century. After five centuries of agricultural expansion, industrialization and urban development, the natural plant cover of this biome is now reduced to only ~12% compared to its original extent. Most of the remaining forest cover (80%) is distributed in small fragments of 50 ha or less (*Figure 2*) (Ribeiro et al. 2011). The current situation of the remaining forest is a worrying factor as well. Just ~1% (2.26 million ha) of the original forest cover and ~9% of the current Atlantic Forest is officially protected (Ribeiro et al. 2011). The Atlantic Forest is not only valuable for its biodiversity richness, but also for the ecosystem services it provides, especially for the people living in Brazil. More than 60% of the Brazilian population lives in the Atlantic Forest area (>100 million people) and depend on the "benefits" provided by properly-functioning ecosystems (Rezende et al. 2015). For example, the shortage of water supply is currently a serious threat for many people living in the region of the Atlantic Forest (Rezende et al. 2015).

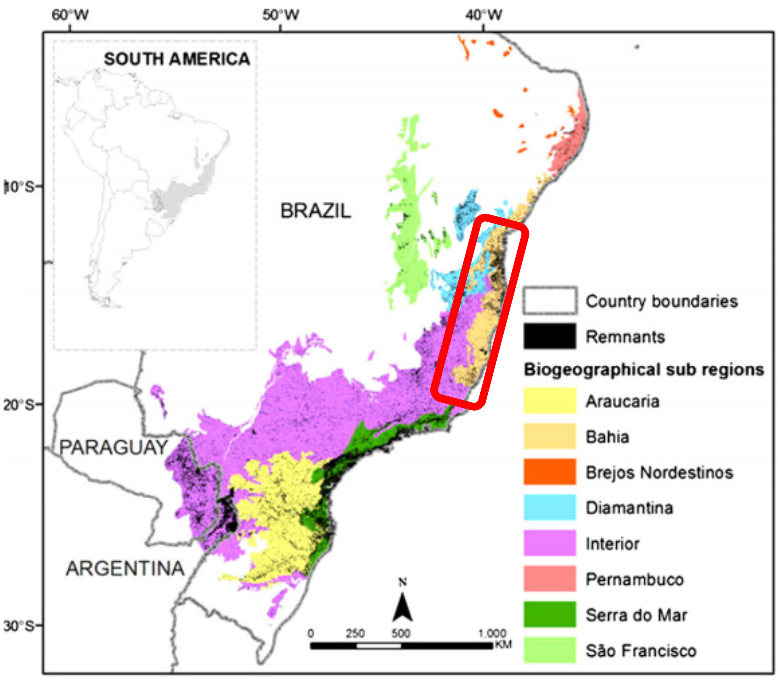


Figure 2. Biogeographic distribution of the Atlantic Forest cover, showing its original extent and current remnants divided into the major sub-regional units. The red square indicates the study site of this paper (source: Tabarelli et al. 2010).

Description of the studied region

The distribution of the Atlantic Forest remnants varies a lot according to each region. *Figure 2* shows that there are basically three regions which are still largely forested: the Serra do Mar region, the south-west region of the Interior Forests (in the Iguaçu region) and the north of the Bahia sub-region (SR). I will focus on the Bahia SR (*Figure 2*). The most forested part of the Bahia SR is characterized by a landscape composed of a mixture of natural forests and shaded cocoa agroforests, locally known as *cabrucas*. Cocoa (*Theobroma cacao*) cultivation began in this region in the eighteenth century and it is still nowadays one of the most important economic activities in the states of Bahia and Espirito Santo (*Figure 3*) (Rolim & Chiarello A.G. 2003).

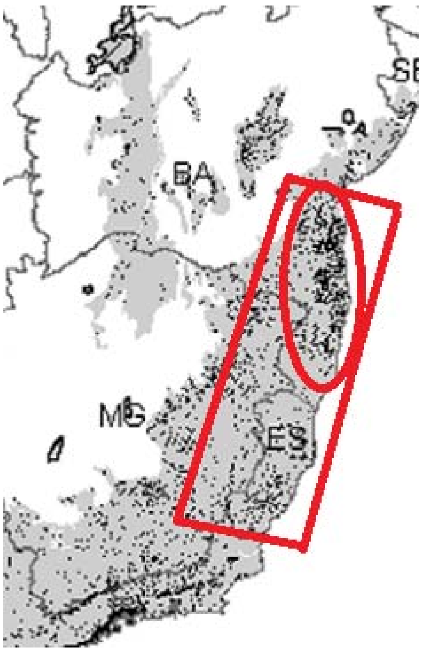


Figure 3. *Close up of the researched region in this paper, original Atlantic Forest extent (grey area) and the remaining forest (black dots) in the north-eastern Atlantic Forest Biome. The red square marks the area, where I am analyzing the choices of small-scale farmers related to agroforestry. The red circle marks the highly forested region of southern Bahia, characterized by a landscape composed of a mixture of natural forests and (mainly*

cacao) agroforests. The darker grey lines delineate the borders of the different Brazilian states. BA Bahia; MG Minas Gerais; ES Espirito Santo.

Like other regions of the Atlantic Forest, the Bahia SR has also been affected by deforestation and forest degradation in the last decades. In the late 1980´s the cocoa production was severely impacted by falling international cocoa prices and the arrival from the Amazon of the devastating fungus *Moniliophthora perniciosa*, causing “witches broom” disease (Cassano et al. 2009). After this crisis many cocoa farmers sold their shade trees for timber and converted their lands into pastures or planted other less environmentally friendly crops (Canale et al. 2013). In recent years, other factors have been altering and threating the highly forested landscapes of Bahia and Espirito Santo. Nowadays, the biggest threats to the region´s biodiversity and rainforests are the expansion of eucalyptus-monocultures and pastures for livestock (SOS Mata Atlântica 2017; Amigo 2017). According to a study conducted by the non-governmental organization *SOS Mata Atlântica* and the *Instituto Nacional de Pesquisas Espaciais* (2017) Bahia was the state with the highest deforestation rate in the Atlantic Forest between 2015-2016. Between 2015 to 2016 the whole Atlantic Forest experienced a 60% and Bahia a 207% (12,288 ha) increase in deforestation rate compared to the year 2014 to 2015. (SOS Mata Atlântica & Instituto Nacional de Pesquisas Espaciais 2017). This was the highest deforestation rate in the Atlantic Forest and also the highest rate in Bahia during the last decade (SOS Mata Atlântica & Instituto Nacional de Pesquisas Espaciais 2017).

Nevertheless, the states of Bahia and Espirito Santo still harbor large areas that are highly forested (*Figure 3*). Especially, the southern part of Bahia is still covered by an “agroforestry-native forest” mosaic (*Figure 3*). Over 50% of the land in southern Bahia is covered by “forested environments”; mainly *cabrucas* (shaded cocoa plantations) (26% of the landscape), secondary forests (19%) and primary forests (9%) (Landau et al. 2008). According to Landau et al. (2008) approximately 600,000 ha in southern Bahia are occupied by *cabrucas*. These systems are characterized by thinned out native forest, where cocoa is being planted on the understory (Rolim & Chiarello 2003). In *cabrucas* part of the forest is kept, because cocoa trees need some shading for production and fruit development (Rolim & Chiarello 2003). Besides this, shade trees are important for protecting the cocoa trees against winds and decrease the risk for biological diseases such as pests, insects or fungus (Johns 1999). Nowadays, the *cabrucas* play also an important role for the conservation of biodiversity in the Bahia SR (Cassano et al. 2009).

Moreover, the region of southern Bahia together with the northern part of Espirito Santo forms a center of species endemism, containing a great diversity of flora and fauna within the Atlantic Forest biome (Rolim & Chiarello 2003). A study carried out by Martini et al. (2007) compared 23 world sites famous for its high densities of arboreal species, and they concluded that southern Bahia was the site with the second highest tree species density in the world. This and many other studies demonstrate the biological diversity found in southern Bahia, pointing out this region´s importance for biodiversity conservation (Flesher 2015; Rolim & Chiarello 2003; Martini et al. 2007; Cassano et al. 2012; Cassano et al. 2014).

Aim and justification of research area and topic

According to a literature review (doing a thorough search in November 2017 using the search engines *Scopus*, *Web of Science* and *Google*) there are almost no scientific studies that analyze the motivations and limitations for farmers to implement new or continue their existing agroforest systems in the Atlantic Forest of Brazil. My previous experience with agroforestry in the mentioned region (in southern Bahia, Figure 3) in 2015 supports the findings of this initial literature review on the current research gap and adds to understand the characteristics of the region and its socio-economic background.

Since the analysis of the value of agroforest systems to support the regional biodiversity is broad and very difficult to investigate, this paper investigates to what extent agroforest systems in southern Bahia can serve as habitat for 3 endangered emblematic animal species. The chosen animal species are the golden-headed lion tamarin (GHLT) (*Leontopithecus chrysomelas*), the maned sloth (*Bradypus torquatus*), and the golden-bellied capuchin (GBC) (*Sapajus xanthosternos*). The selected species have a high conservation priority and value, due to their endemism and their high risk of extinction. Furthermore, these animals can act as umbrella species, meaning that while conserving their habitat and ecosystem, other species living on it would be protected as well. Besides the value of agroforest systems for conserving the local biodiversity, it is important to understand what motives and barriers exist for small scale farmers related to the implementation of these systems. Thus, this paper investigates the motivations and limitations for small scale farmers to create agroforest systems as well.

Description of the three analyzed animal species

The GHLT is an arboreal endangered primate that can only be found in the state of Bahia (Zeigler et al. 2012). The habitat of GHLTs are lowland mature forests and secondary/regenerating forests (Zeigler et al. 2012). Their diet consist of plants, fruits, flowers, nectar, insects and small invertebrates (Rylands 1993). GHLTs usually live in groups of 4 to 7 individuals and their home range is normally between 40 to 320 hectares (Rylands 1993).

The maned sloth is an arboreal folivore endemic to the Atlantic Forest (Chiarello & Moraes-Barros 2015). Its largest and most genetically diverse population is located in southern Bahia (Falconi et al. 2015). The maned sloth is classified as vulnerable according to the IUCN Red List of Threatened Species (Chiarello & Moraes-Barros 2015). This species inhabits predominantly evergreen forests, but they can also live in semi-deciduous and secondary forests (Chiarello & Moraes-Barros 2015). The home range of individual maned sloths is approximately between 0,5 to 30 ha (Falconi et al. 2015).

The GBC is a frugivore-insectivore arboreal primate endemic to the state of Bahia (Kierulff et al. 2015). This species is classified as critically endangered, and their largest populations are found in southern Bahia (Canale et al. 2013). GBC´s habitat consists of tropical lowland and submontane forests, but they can also be found in semi-deciduous forests in the western part of the state of Bahia (Kierulff et al. 2015). GBCs live normally in groups formed by approximately 10 to 30 individuals, and the groups home ranges can extend to 1,000 ha (Canale et al. 2013).

Research questions

This paper investigates the mentioned topics using two methods. First, a literature review was done based on a pre-defined search strings in literature databases. The second method was the use of questionnaires with the participation of small scale farmers working with agriculture and agroforestry in the Bahia SR. Thus, the following questions are addressed in this paper:

1. To what extent can agroforestry systems in southern Bahia provide habitat for the golden-headed lion tamarin, the maned sloth and the golden-bellied capuchin (from a landscape and farm scale perspective)?

2. To what extent is agroforestry a viable option for small scale farmers in the Bahia sub-region of the Atlantic Forest?

3. What barriers exist for small scale famers and how could these be overcome to increase farmer's willingness to apply agroforestry?

Methods

Literature review

To investigate, to what extent agroforest systems can serve as habitat for the GHLT (*Leontopithecus chrysomelas*), the maned sloth (*Bradypus torquatus*), and the GBC (*Sapajus xanthosternos*) a literature review was done using the scientific databases ISI *Web of Science* and *Scopus* to find scientific papers. To limit the number of papers, only studies published since 1992 were included in the search. The following search strings were used in *Web of Science* and in *Scopus*: “Atlantic Forest agroforestry” (200 results), “Bradypus torquatus” (79 results), “Sapajus xanthosternos” (30 results), and “Leontopithecus chrysomelas” (201 results).

The articles had to study the following aspects for being chosen for this paper: they had to be carried out in the region of southern Bahia, and they had to focus on the use of agroforest systems by one or more of the selected species. From the **510** results, **18** articles were found with the mentioned characteristics. Three investigations studied two of the researched species, therefore in total the following number of studies were found for each species: **11** for the GHLT, **6** for the maned sloth and **4** for the GBC. The chosen studies analyzed the use of agroforest systems (mainly *cabrucas*) as habitat by one or more of the researched species in southern Bahia. With the literature review I aimed at answering mostly the first research question.

Questionnaires

Questionnaires were sent to small scale farmers working with “conventional agriculture” and with agroforestry in or next to the Bahia SR. The questionnaires aimed at providing information for answering the three research questions, but they are especially related to the second and third research questions.

I used specific criteria for answering the **second research question**. The criteria I used were:

A) Is it economically viable to use agroforest systems – more profitable than other land uses (such as pasture with livestock or monocultures)?
B) How are the available support mechanisms (such as support programs, practical knowledge and examples of the region, monetary incentives, or loans) used for promoting agroforest systems?
C) What are the risks and disadvantages associated to the implementation of agroforest systems?

There are **77** agroforestry and **68** “conventional agriculture” small scale farmers that received and answered the questionnaires. The aim of this paper was to include at least 60 agroforestry and 60 “conventional agriculture” small scale farmers that where living and working in or next to the Bahia SR. Thus, I took contact with three different organizations working with agroforestry and “conventional agriculture” that could provide me with the desired number of respondents. The names of the organizations are: *Povos da Mata*, *Instituto Capixaba de Pesquisa*, *Assistência Técnica e Extensão Rural* (*INCAPER*) and *Iracambi*. *Povos da Mata* is a cooperative or association of smallholder farmers working with certification mechanisms of agroforest systems in the state of Bahia. *INCAPER* is a state-owned institute working with research, rural extension, and technical assistance related to small scale agriculture and sustainability in Espirito Santo. *Iracambi* is a non-profit organization located in the “Zona da Mata” (Forest Zone) in the state of Minas Gerais, near the southwest of Espirito Santo. This organization works with biodiversity conservation, research, and the improvement of rural livelihood through forest based incomes.

The farmers that work with agroforest systems according to the definition of agroforestry stated in this paper where classified as “agroforestry” respondents and the farmers that did not classified in this definition of agroforestry were classified as “conventional agriculture” respondents. The questions that were made in the questionnaires can be found in *Appendix I*. The questionnaire (*Appendix I*) was translated into Portuguese and then sent to the farmers through the three mentioned organizations.

Analysis of the questionnaires

The answers of people working with farms that had an utilized agricultural area bigger than 50 hectares were excluded from the results, because this is one of the criteria for defining small scale farmers according to the Brazilian Atlantic Forest Law. For this reason, **2** answers were removed from the results of farmers working with agroforestry and **4** answers were removed from the results of “conventional agriculture”. Thus, this research analyzes in total **75** small scale farmers working with agroforestry and **64** smallholder farmers working with “conventional agriculture”. From the answers of people working with agroforestry 57% lived in southern Bahia, 12% in Espirito Santo and 30% in Minas Gerais (close to the southwestern part of the state of Espirito Santo). From the answers of people working with conventional agriculture 5% lived in southern Bahia, 28% in Espirito Santo and 67% in Minas Gerais (close to the southwestern part of the state of Espirito Santo).

One aspect that is important to point out is that not all the farmers answered all the questions, therefore there are different number of responses per question.

I only asked to the farmers working with agroforestry in southern Bahia about the occurrence of the three analyzed species on their lands. I decided this, because southern Bahia is the region with the highest conservation value for the three analyzed species, and the GHLT and the GBC occur just in the state of Bahia.

The information related to the monthly income of farmers working in Espirito Santo was excluded from the results, since the numbers were very high, and it could not be corroborated whether the answers were per hectare or for the whole farm.

Limitations of my research

The methods I used for answering the three research questions have their limitations and weaknesses as well. Regarding the literature review, not all the studies used the same methodology. Besides this, the studies analyzed different aspects of the use of agroforest systems by the analyzed animal species. With the information of the analyzed studies it is possible to say to what extent can agroforest systems be used as habitat by the three analyzed animal species, but for providing more precise and accurate information it would have been useful to support the findings with field research on site. Thus, the part of the questionnaires that addresses the acceptance and presence of wild animals on the farmer´s lands is intended to support the literature review to a certain extent.

The use of questionnaires with pre-defined choices for analyzing farmers thoughts and decisions related to agroforestry is a method that has its limitations as well. First of all, it is important to point out that the categorizations of farmers working with agroforestry or "conventional agriculture" depended on the definition of agroforestry stated in this paper. The most important aspect to differentiate "conventional agriculture" and agroforestry was the use of **woody perennials** with **agricultural crops and/or animals** in the **same land-management unit**. However, the questionnaires were delivered to the farmers by the three mentioned organizations (*Povos da Mata*, *INCAPER*, and *Iracambi*). Therefore, the organizations differentiated "conventional agriculture" and agroforestry according to my definition, but the final selection of which farms classified to which category depended on their judgement. Another weakness of this approach is that the analyzed data is based on the trust of the organizations working according to my criteria and the results are also based on the trust in farmers giving reliable data. For improving this used methodology, it would have been better if I would have visited the farms on site and conducted the questionnaires myself on site. Additionally, while being on site I would also have been able to conduct qualitative interviews and not only the use of pre-defined questionnaires.

Results

Literature review

A literature review was done for answering the first research question: To what extent can agroforest systems in southern Bahia provide habitat for the three analyzed animal species (from a landscape and farm scale perspective)? A list of the analyzed papers per species is found in *Appendix II*.

There were **11** studies that analyzed the presence of GHLTs in agroforests in southern Bahia (*Appendix II*). All studies confirmed the importance of agroforest systems (mainly *cabrucas*) as habitat for the endangered GHLT. There are even breeding groups of GHLTs that survive and reproduce entirely in *cabrucas* (Oliveira et al. 2011). However, there is no evidence that supports the idea of entire populations of GHLTs living only in *cabrucas* without the need of nearby undisturbed habitat (Cassano et al. 2009; Cassano et al. 2012; Cassano et al. 2014).

Several studies also analyzed which plant species GHLTs use as food sources, sleeping sites or for animal prey foraging. According to Oliveira et al. (2011) the non-native jackfruit was the most consumed species by the GHLTs in *cabrucas* and was widely available and used throughout the year. The jackfruit is a widely commercialized fruit in the Bahia SR, but none of the analyzed studies mentioned conflicts between farmers and GHLTs due to the consumption of this plant species (Oliveira et al. 2010; Oliveira et al. 2011; Catenacci et al. 2016). Trees that support large bromeliads promote the presence of GHLTs as well, since these plants are an extremely important animal prey foraging site, and they also provide fruits and sleeping sites for the GHLTs (Oliveira et al. 2010; Oliveira et al. 2011; Catenacci et al. 2016). The most exploited plant families by the GHLTs are the *Myrtaceae* and the *Sapotaceae*, however they are less commonly found in *cabrucas* (Catenacci et al. 2016; Oliveira et al. 2010). Including the above-mentioned species in *cabrucas* or other agroforest systems favors the occurrence of GHLTs.

There were **4** studies that investigated the use of *cabrucas* by maned sloths in southern Bahia and **2** studies in Espirito Santo (in total **6** studies) (*Appendix II*). One important aspect to point out about maned sloths is that they have very small home ranges (from 0,5 to 30 ha) and they are generally bad in crossing large (and even small) non-forested areas as they are slow and almost never leave their trees (Falconi et al. 2015). This is different compared to the other two analyzed species who can more easily travel across gaps and even through smaller non-forested areas, such as paths or roads. The studies carried out in southern Bahia concluded that *cabrucas* play an important role as habitat for the maned sloths (Cassano et al. 2009; Cassano et al. 2012; Cassano et al. 2011; Falconi et al. 2015). The researches done in Espirito Santo demonstrated that maned sloths use *cabrucas* as part of their habitat as well (Chiarello 1998; Santos et al. 2016). Several studies showed that maned sloths select their habitat depending much more on the tree species found at finer scales and not so much depending on the landscape structure (Cassano et al. 2011; Falconi et al. 2015; Santos et al. 2016). The maned sloths are very selective towards forested areas characterized by complex vegetation structures (high density of trees, connected crowns, closed and dense canopies), and they also prefer large trees with lianas and bromeliads (Falconi et al. 2015; Santos et al. 2016). Thus, maned sloths can effectively occupy (and even select for) disturbed forest habitats, such as *cabrucas* (Falconi et al. 2015). However, the studies that analyzed the use of *cabrucas* by maned sloths were carried out in a highly forested region, and it is unclear to what extent they can survive in a landscape composed only of disturbed habitats or low proportions of undisturbed habitats (Cassano et al. 2011; Falconi et al. 2015; Santos et al. 2016).

There were **4** studies that analyzed the presence of GBCs in agroforest systems (*Appendix II*). Canale et al. (2013) and Canale et al. (2016) analyzed the habitat use by GBCs in a highly forested landscape in the region of and next to the Una Biological Reserve (in southern Bahia), which is one of the largest forest fragments in the northern Atlantic Forest.

Both studies concluded that agroforest systems in this region serve as habitat for the GBC. GBCs feed from different fruits in the *cabrucas* of the mentioned region (Canale et al. 2016). The most common fruits eaten in these agroforest systems are oil palm, jackfruits and cacao, all of these species are exotic plants that were introduced to Bahia in the 1500s, 1640s and 1740s respectively (Canale et al. 2013). However, *cabrucas* are not used as sleeping sites and GBCs enter these systems carefully, due to the constant presence of dogs and armed humans (Canale et al. 2013).

Flesher (2015) investigated the potential of the Ituberá region to sustain the population of the GBC for 17 years. The region is also located in southern Bahia, and it is characterized by a landscape composed of forests and diverse agroforest systems with 200 cultivars planted (including 60 tree species) (Flesher 2015). Compared to the region of the Una Biological Reserve, the Ituberá region is less forested and the conservation unit found in the region (Michelin Ecological Reserve) is much smaller than the Una Biological Reserve. In this region the GBCs visited the agroforest systems for food sources sporadically, and they entered these systems with extreme caution since they have been severely hunted during the last 6 decades (Flesher 2015).

Cassano et al. (2014) investigated how forest cover and management intensification affected the presence of mammals in *cabrucas* in the region of the Una Biological Reserve. However, this study barely focused on the GBCs and it just mentioned that GBCs were spotted several times in one of the 30 analyzed *cabrucas* during the study.

To resume the findings of the literature review, these are the five main aspects that will determine whether an agroforest system can serve as habitat for any of the three analyzed species:

- hunting pressure
- presence of dogs
- canopy connectivity
- occurrence of plants that make up the species diet
- proximity to forest remnants

Biodiversity conservation value of agroforests is context dependent

It is important to point out that because southern Bahia is highly forest (over 50 % of the land covered by “forested environments” (Landau et al. 2008)), *cabrucas* and other agroforest systems have the potential to serve as habitat for several biological communities. For example, Cassano et al. (2009) compared the overall presence of different biological communities in two regions in southern Bahia that originally belonged to a single “forest-block”. The landscape of Una is composed of 50% forest and 5% *cabrucas*, and the landscape of Ilheus is dominated by *cabrucas* (82%) with only 5% under forests (Cassano et al. 2009). Cassano et al. (2009) concluded that the biological communities were poorer in the *cabruca*-dominated landscape of Ilheus compared to the forest-dominated region of Una, with fewer species of small mammals, bats, birds, ferns, and litter herpetofauna. This suggests that large forest fragments are still needed for sustaining the biodiversity conservation value of *cabrucas*. This also means that a landscape composed mostly of agroforests and little undisturbed habitat is unlikely to retain the original species assemblages. Another study conducted by Cassano et al. (2014) analyzed the presence of different mammals in *cabrucas*, and investigated which of the following two factors affected the conservation value of *cabrucas* the most: the proximity to undisturbed forests or the management intensity in the agroforests. This study was carried out in the region of Una (>50% forests, and around 5% *cabrucas*). Management intensification in *cabrucas* was characterized by the direct effect of reduced canopy cover and the indirect effect of higher frequency of dogs. The study concluded that even if both factors (proximity to forests and management intensification) affected the distribution of mammal species, management intensification influenced the presence of mammals the most, negatively affecting a larger number of species (Cassano et al. 2014). However, the importance of local forest cover and local management intensification are likely to be context dependent. For example, Pardini et al. (2010) showed that in the region of the Serra do Mar in the Atlantic Forest (*Figure 2*) the abundance and richness of specialist mammals increased with forest patch size in a landscape containing an intermediate proportion of remaining forest (30%), but not in more forested (50%) or deforested (10%) landscapes.

Questionnaires

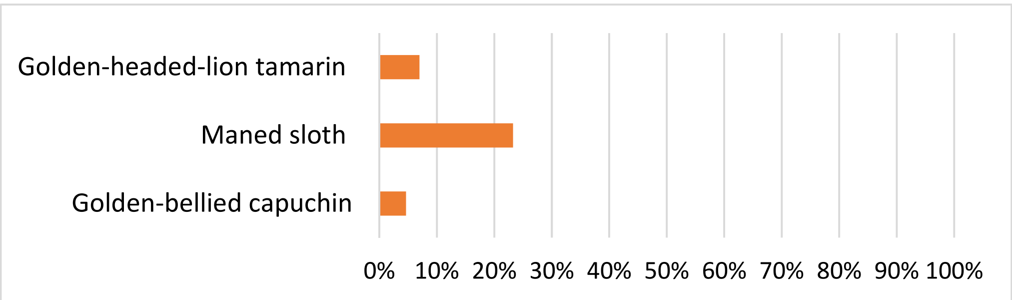
The results of the questionnaires provided information related to the three research questions. The exact questions that were asked in the questionnaire can be found in *Appendix I.*

Characteristics of the two groups of farmers

The farmers that took part on this study had farms that had an utilized agricultural area ranging from 1 to 50 hectares. The average number of plant and animal species per farm in agroforestry systems was around 7 species per farm, and there was a range between 2 to 14 different species per farm. In conventional agriculture the average number of plant and animal species per farm was of approximately 2 species per farm, and there was a range between 1 to 8 different species per farm. As stated in the methods, from the answers of people working with agroforestry: 57% lived in southern Bahia, 12% in Espirito Santo and 30% in Minas Gerais (close to the southwestern part of the state of Espirito Santo). From the answers of people working with conventional agriculture: 5% lived in southern Bahia, 28% in Espirito Santo and 67% in Minas Gerais (close to the southwestern part of the state of Espirito Santo).

First research question

There were 42 farmers working with agroforestry in southern Bahia and all of them answered the question related to the occurrence of the three analyzed species on their farms (*Figure 4*). The maned sloth was the most common "emblematic species" found in the



analyzed farms. According to the results of the questionnaire the maned sloths occurred in 23% of the agroforest systems, compared to 7% for the GHLT and 5% for the GBC.

Figure 4: Percentage of agroforestry farmers in southern Bahia that confirmed the presence of the analyzed species on their farms.

The presence of different animal species and animal groups in the farms was also compared between agroforestry systems (75 responses) and conventional agriculture (64 answers) (*Figure 5*). Every analyzed animal group was more commonly found in agroforest systems than in farms working with conventional agriculture. The largest difference between both systems was found in the category of "other large mammals" (such as peccary, deer). 52% of the farmers working with agroforest systems confirmed the presence of "other large mammals" in their lands, compared to only 8% in conventional agriculture. In other words, it is 44% more likely to find (other) large mammals in agroforest systems than in lands working with conventional agriculture.

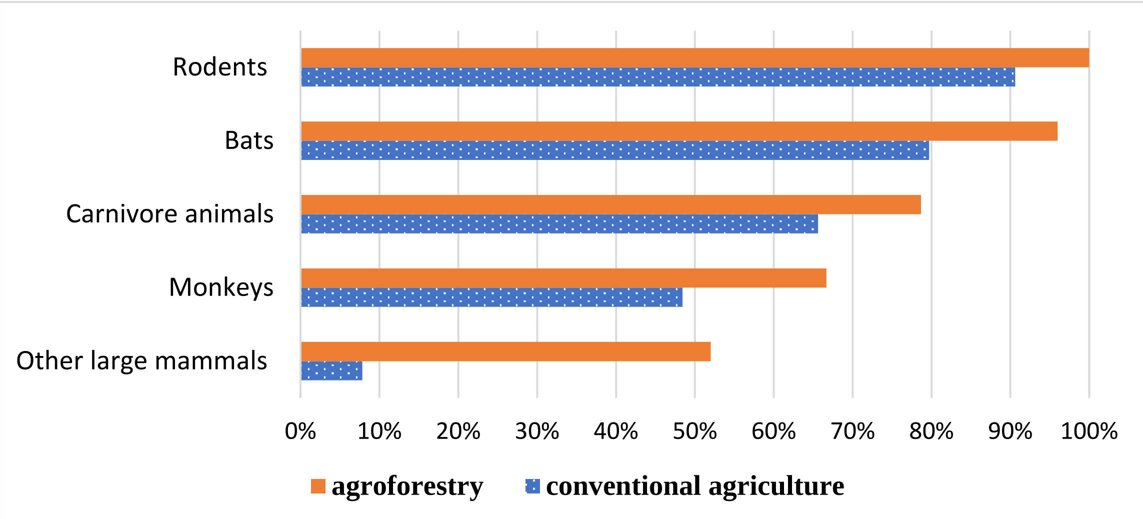


Figure 5: Percentage of animal species found in agroforest systems and conventional agriculture.

There were 74 answers to this questions for farmers working with agroforestry, from those answers 93% liked and 7% did not like wild animals on their farms. From the 63 responses of the farmers working with conventional agriculture 87% like and 13% did not like the presence of wild animals on their lands.

The reasons why agroforestry (70 answers) and conventional agriculture (56 responses) farmers liked wild animals in their lands were: 96% of agroforestry farmers and 73% of conventional agriculture farmers believed that wild animals have also the right to live on their farms, and 36% of agroforestry farmers and 79% of conventional agriculture farmers thought that wild animals can act as "regulators" on their lands and thus avoid biological diseases.

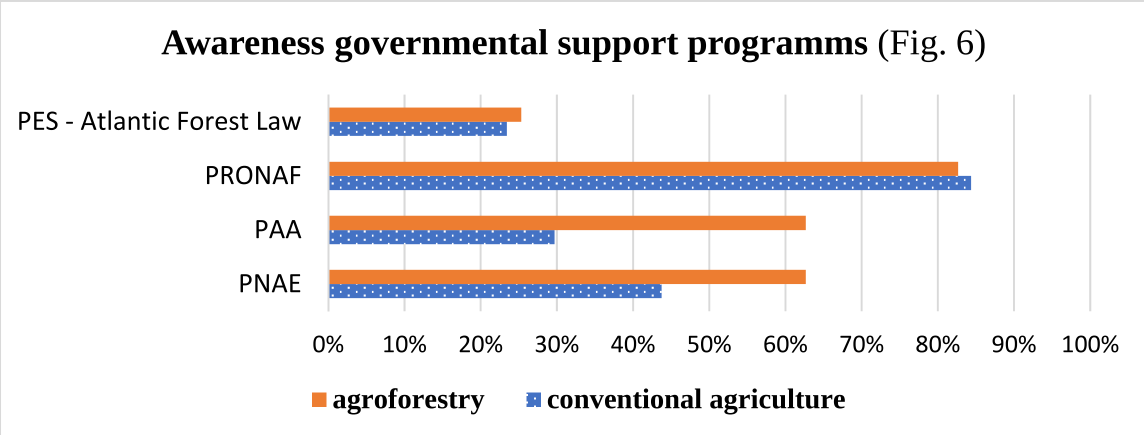
The reasons behind why agroforestry (9 answers) and conventional agriculture (8 responses) farmers did not like wild animals on their farms were: 56% of agroforestry farmers and 88% of conventional agriculture farmers did not like that wild animals could damage their crops or livestock, 33% of agroforestry farmers and 50% of conventional agriculture farmers thought that wild animals can damage their household and the items in it, and 33% of agroforestry farmers and 38% of conventional agriculture farmers believed that wild animals can bring pests and diseases to their lands.

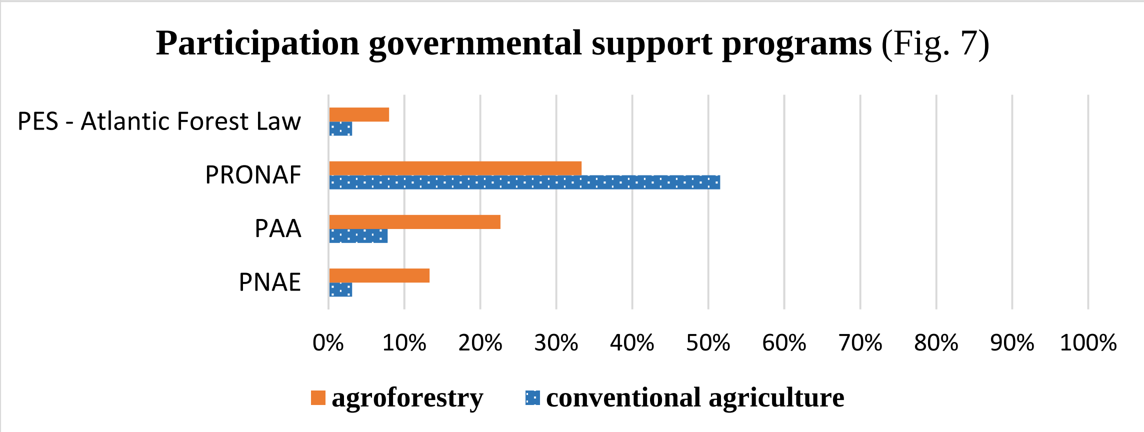
39% of agroforestry farmers and 3% of conventional agriculture farmers mentioned other reasons why they liked or disliked wild animals. The most frequently (other) mentioned reason was that it is simply nice and beautiful to see and have wild animals on their lands. Several farmers also mentioned that often peccaries eat their planted manioc (*Manihot esculenta*), rodents eating their cocoa and foxes eating their chicken, and that these were normally the only reasons of why farmers disliked wild animals on their farms.

Second and third research questions

There are 59 farmers working with agroforestry and 31 farmers working with conventional agriculture that answered about their monthly income during 2015 to 2017 (3 years). According to the responses, the average **monthly income per hectare** of **agroforestry systems** was of **245 R$** [standard error of the mean=51 R$, median=133 R$] (Brazilian real) and for farmers working with **conventional agriculture** it was **568 R$** [standard error of the mean=152 R$, median=233 R$].

Out of all the agroforestry (75) and conventional agriculture (64) responses, *Figure 6* and *7* show the percentage of farmers that are aware of and participate in the most commonly used agricultural/agroecological governmental support programs in the Atlantic Forest region (most commonly used governmental support programs according to Porro &





Miccolis 2011).

Figures 6 & 7: Awareness of the existence of (Figure 6) and participation in (Figure 7) governmental agricultural/agroecological support programs. PES Payment for ecosystem services; PRONAF Programa de Fortalecimento da Agricultura Familiar; PAA Programa de Aquisição de Alimentos; PNAE Programa Nacional de Alimentação Escolar

Figure 8 shows the different perceptions that small scale farmers have related to intercropping their crops or livestock with woody perennials. There were 73 answers of farmers working with agroforestry and 63 of farmers working with conventional agriculture. In total, almost half of all the farmers (58% agroforestry; 40% conventional agriculture) think that intercropping with woody perennials can increase the income and production in their lands in the long term. Farmers working with agroforestry see more economic advantages in intercropping compared to conventional agriculture farmers (see increase and decrease in income: short and long term). Most farmers (especially the ones working with agroforestry: 69% compared to 52% of conventional agriculture) believe that intercropping with woody perennials increases the quality of the soils.

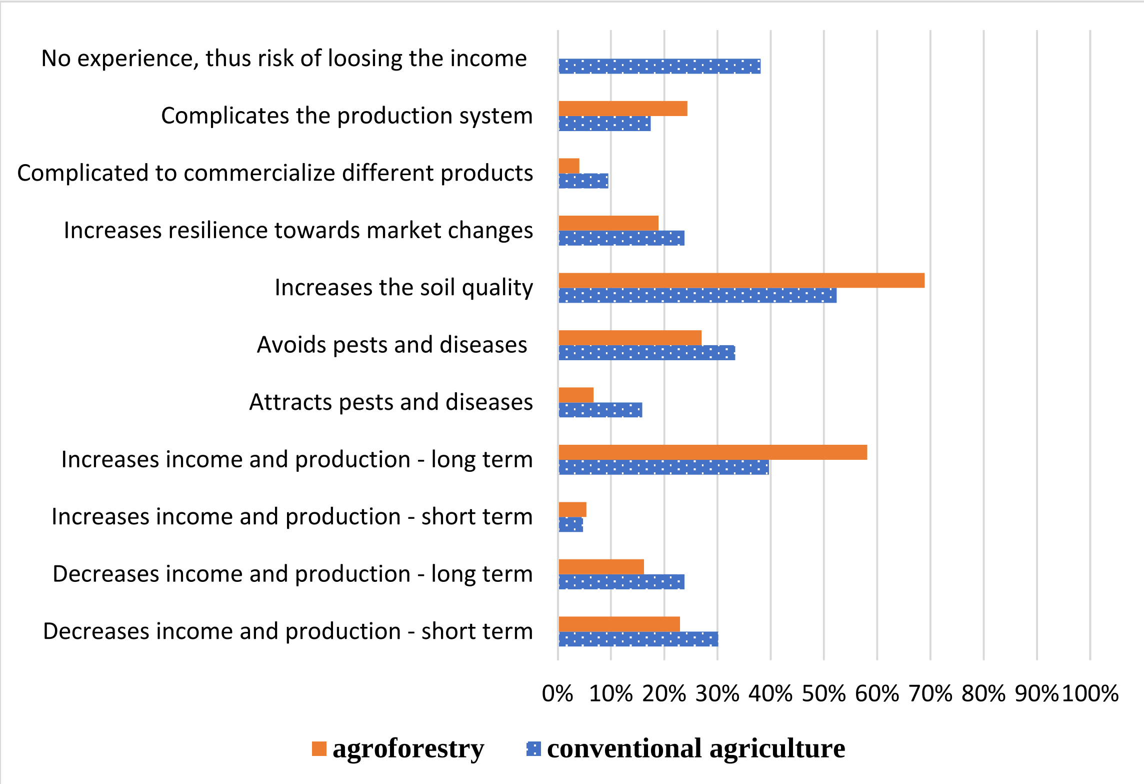


Figure 8: Different perceptions of farmers related to intercropping their crops or livestock with woody perennials.

Conventional agriculture farmers where asked whether they would like to intercrop their current agricultural field with woody perennials and thus also take a risk in their income. From the 64 answers **55%** said that they **would like to intercrop woody perennials** with their current crops or livestock and **45% would not like to intercrop**.

Figure 9 shows the reasons or perceived benefits for agroforestry farmers (74 responses) to work with agroforestry compared to working with conventional agriculture. *Figure 9* also shows what do conventional agriculture farmers expect or perceive as benefits if switching their current practices to agroforestry systems, in other words intercropping their lands with woody perennials. There were 35 answers of conventional agriculture farmers, these answers are from those farmers that confirmed that they would like to intercrop more woody perennials with their current agricultural practices.

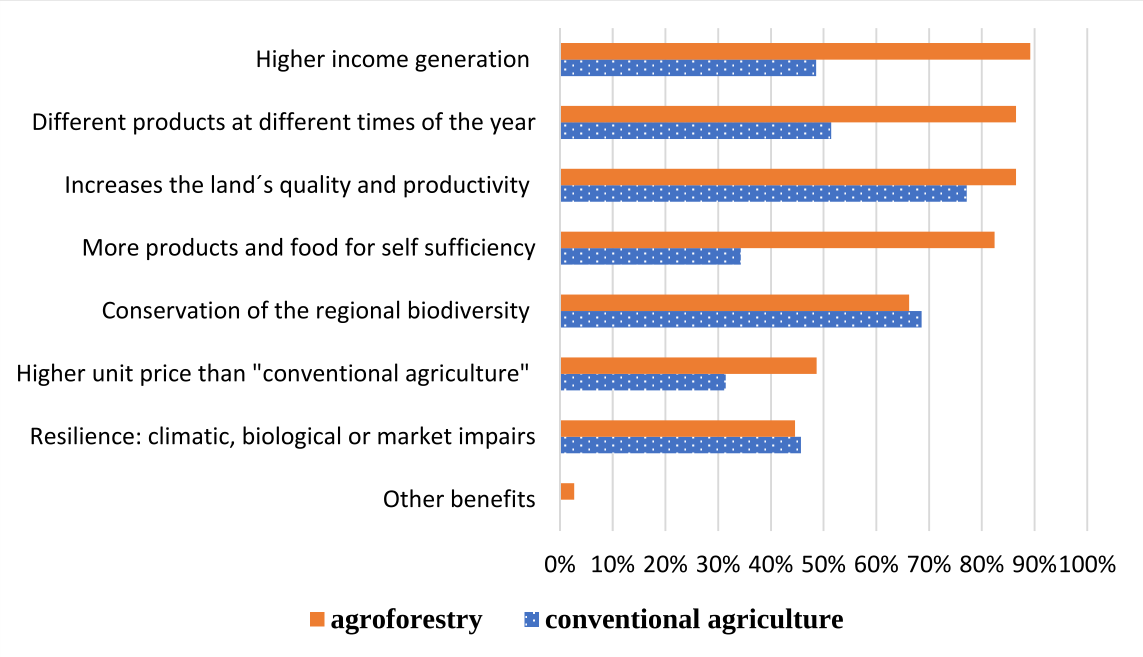


Figure 9. Perceived benefits of working with agroforestry compared to conventional agriculture by agroforestry farmers. Expected benefits of conventional agriculture farmers if intercropping their lands with woody perennials.

Agroforestry farmers link more benefits to intercropping with woody perennials in most categories than conventional agriculture farmers (Figure 9). It is important to point out that 89% of agroforestry farmers believe that working with agroforestry systems generates more income than working with conventional agriculture. On the other side, 49% of conventional agriculture farmers think that intercropping their crops with woody perennials would increase their income. It is also evident that agroforestry farmers link more product diversity and food security as an important benefit of agroforestry. Much fewer conventional agriculture farmers perceive that the last two mentioned aspects are important benefits of agroforestry systems.

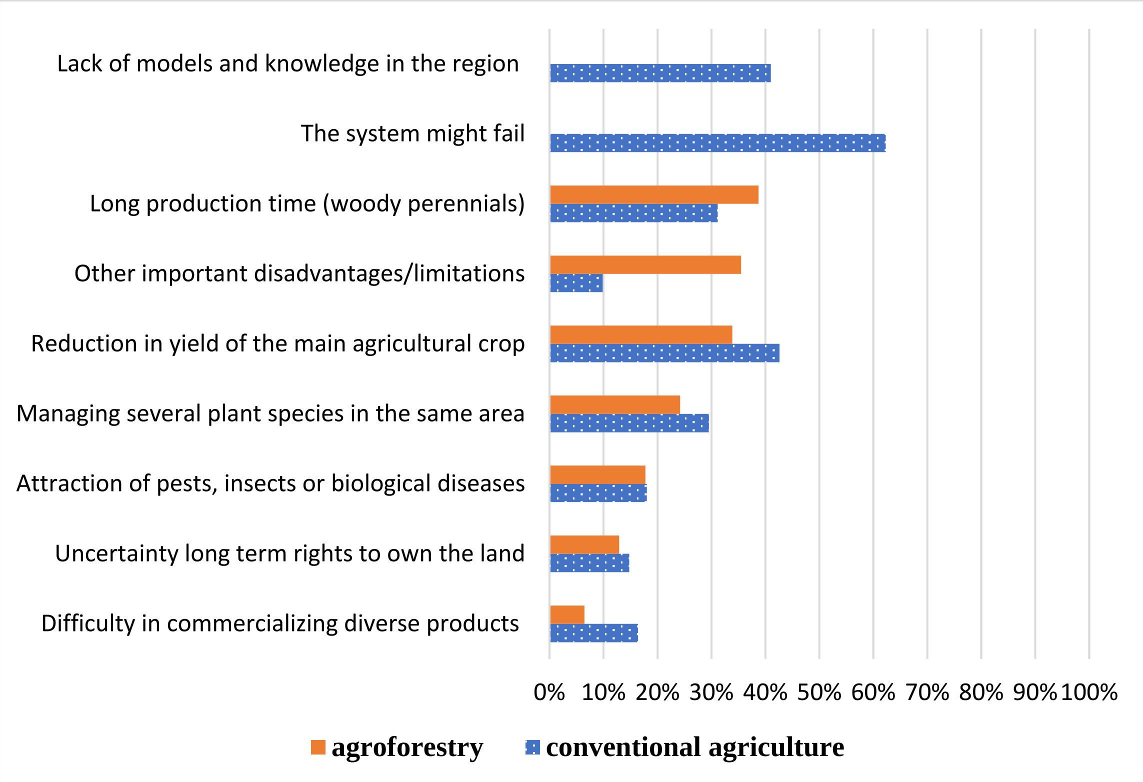


Figure 10. Perceived limitations and drawbacks of working with agroforestry (answered by farmers working with agroforest systems). Expected limitations and drawbacks related to intercropping agricultural fields with woody perennials (answered by farmers working with conventional agriculture).

Figure 10 shows what agroforestry farmers perceive as the main limitations or drawbacks of working with agroforestry (62 answers). *Figure 10* also shows what do conventional agriculture farmers (61 answers) perceive as the main limitations and drawbacks of intercropping their crops or livestock with woody perennials. The number of responses of conventional agriculture farmers are from those farmers who expressed that they would like and also from the farmers that would not like to intercrop with woody perennials in their lands. The perceived limitations and drawbacks related to agroforestry was similar between agroforestry and conventional agriculture farmers. In the "other" limitations of working with agroforestry category the most commonly named drawbacks were: 12 farmers mentioned the lack of extra free space for planting, 4 farmers working with agroforestry mentioned the difficult access to get seedlings in their region, and 3 farmers working with conventional agriculture pointed out that the lack of water was a main limitation for implementing woody perennials.

Discussion

Distinguishing agroforest systems from conventional agriculture in the questionnaires

As stated in the limitations of my methods it was up to the three organizations that sent the questionnaires to judge which farms fitted into my definition of agroforest systems and which ones did not. The farms that did not fit into this definition where classified as conventional agriculture. In most tropical regions (including the studied region; confirmed by the received data) it is not so easy to differentiate between agroforest systems and conventional agriculture, because most farmers plant anyways more than one plant species on their lands and the degree of how much land is being intercropped varies among farms (Atangana et al. 2014). Therefore, it is important to remember that the results presented through the questionnaires of this research are based on a definition of agroforestry that allows the inclusion of very different types of agroforest systems, ranging from farms working with only two to fourteen different species. On the other side, the average number of species in the studied agroforest systems is 7 and the corresponding number for farms working with conventional agriculture is 2. Thus, there is actually a big enough difference between the number of species per farm, which shows that the studied agroforest systems and the analyzed farms working with conventional agriculture have marked differences in their species and structural composition. Moreover, more than half of the agroforestry answers (57%) are from farmers working with highly diverse agroforest systems in southern Bahia.

The following subsections are related to the first research question

The use of agroforest systems as habitat by the golden-headed lion tamarin, the maned sloth, and the golden-bellied capuchin

The literature review showed that the three researched species visited or inhabited agroforest systems (mainly *cabrucas*) in the region of southern Bahia. The GHLT and the GBC play an important role as seed dispersers for native and also for non-native tree species in the Bahia SR (Cardoso et al. 2011; Canale et al. 2016). Especially the GBC is one of the largest fruit eating mammals in the Bahia SR and they have home ranges that extend up to 1,000 ha, and several endemic and threatened plant species rely on their seed dispersion (Canale et al. 2016). Seed dispersal is an important service provided by the GHLTs and the GBC in the Bahia SR and thus they are also indirectly dispersing seeds of different plant species into the *cabrucas* (Oliveira et al. 2010; Canale et al. 2016), however none of the analyzed studies pointed out any important synergistic relationship between agroforestry systems and the analyzed species. The GHLT was the species that visited and inhabited *cabrucas* the most. Agroforest systems that contain jackfruits, large bromeliads, or trees from the *Myrtaceae* and *Sapotaceae* families (used for shade purposes) are more likely to attract GHLTs (Catenacci et al. 2016; Oliveira et al. 2010; Oliveira et al. 2011). However, trees of the *Myrtaceae* and *Sapoteceae* families are less commonly found in *cabrucas*, since understory cleaning (which is a part of the *cabruca* management) usually eliminates these slow-growing species (Oliveira et al. 2010). Moreover, farmers gradually replace trees of these families with exotic species that generate commercial fruit crops (Oliveira et al. 2010). The maned sloth was the second species that was more likely (compared to the GHLT and the GBC) to use *cabrucas* as part of their habitat. The GBC has a low probability of using agroforest systems in southern Bahia (Cassano et al. 2014). But agroforest systems are still being used by GBCs in the mentioned region (Flesher 2015). GBCs enter these systems with extreme caution to consume mainly exotic fruits, such as jackfruit, cacao and oil palm (Canale et al. 2013; Canale et al. 2016).

If agroforestry systems will be used as part of a conservation strategy for any of the analyzed species it is also important to understand if farmers would like to implement the recommended measures for making their system more “friendly” towards the analyzed species. From the five mentioned factors in the results section that influence the occurrence of the analyzed species in agroforest systems the most, there are especially two aspects that farmers could implement without diminishing the yield in their lands. These are: controlling domestic dog populations and stop hunting (Cassano et al. 2012; Cassano et al. 2014). Hunting is actually illegal throughout the Atlantic Forest, however this law is generally not enforced (Cassano et al. 2009). People in the Bahia SR hunt animals as food sources, however the hunting pressure is actually declining due to the Atlantic Forest Law that prohibits hunting, and because hunting is becoming more of a leisure activity instead of a need for subsistence, also most of the rural youth prefer town life for recreation (Flesher

2015). Hunting is not solely focused on human-modified landscapes, but there is also hunting pressure in forest remnants (Cassano et al. 2012). Therefore, protected areas play an important role in this matter, since these areas protect the animals from hunting activities. The species that would benefit the most from controlling the dog populations and reducing the hunting pressure would likely be the GBC, since this species avoids human contact as much as possible when hunted (Flesher 2015). The canopy connectivity plays also an important role for promoting the occurrence of arboreal animals (such as the three studied species) in agroforest systems (Cassano et al. 2014). However, increasing the shade cover within agroforests should be implemented carefully, since this could affect the productivity of the crops (such as cocoa) that are underneath the shade trees (Cassano et al. 2014). The farmers owning the agroforest systems want to maintain a good yield as well and they may not be willing to increase the canopy connectivity “just” to promote the conservation of certain animals (Cassano et al. 2014). Cassano et al. (2014) recommend that instead of obtaining high canopy connectivity through high tree densities, it may be better to improve connectivity through the planning of specific pathways and maintaining specific tree species.

The factors that would support the conservation of the three analyzed species in agroforest systems can be extrapolated to other animal species to a certain extent. First, since the analyzed species have a high conservation value, they can act as umbrella species. This means that if agroforest systems would be managed in the recommended way, other plants and animals could potentially use these systems as part of their habitat as well. Also several studies in southern Bahia give similar recommendations on focusing on the five mentioned factors (hunting, dog presence, canopy connectivity, occurrence of plants that make up the species diet, proximity to forest remnants) for supporting the conservation of other terrestrial or scansorial mammal species in agroforest systems (Cassano et al. 2009; Cassano et al. 2012; Cassano et al. 2014; Flesher 2015). Additionally, *cabrucas* in southern Bahia play an important role as habitat or as buffer zone for most of the flora and fauna found in the forests of southern Bahia (Cassano et al. 2009). The five recommended factors for making agroforest systems suitable for supporting the conservation of the three analyzed species would therefore also promote the conservation of several mammal species (and probably other animal species as well). The only factor that plays a more important role for the analyzed species than for other terrestrial mammals is the canopy connectivity. Even if canopy connectivity is still important for terrestrial and scansorial mammals, this aspect is much more decisive for arboreal mammals (Cassano et al. 2014).

Presence and acceptance of wild animals in the farms

According to the farmers living in southern Bahia, from the three analyzed species the maned sloth was the species most commonly found in the agroforest systems of this region (southern Bahia) (*Figure 4*). The maned sloth visited or inhabited 23% of the agroforest systems in southern Bahia. In southern Bahia, the maned sloth was therefore around 3 times more frequent in agroforests than the GHLT (7%) and more than 4 times more frequently found in agroforests than the GBC (5%). These findings differ from the studies carried out by Cassano et al. (2009), Cassano et al. (2012) and Cassano et al. (2014), where the most commonly found species in agroforest systems was the GHLT, followed by the maned sloth and where the GBC was rarely found in the agroforests. It is worth noting that the presented results are based on the trust and written answers by the farmers, and no camera traps or other methods were used in this research to corroborate the findings of the presence of different animal species on the farms. Another possible explanation to the different results between this research and the studies carried out by Cassano et al. (2009, 2012, 2014) is that the agroforests analyzed by Cassano et al. (2009, 2012, 2014) were from a different region in southern Bahia than the ones analyzed in this investigation. The GHLT can be more present in some areas of southern Bahia and the maned sloths more present in other areas, and this would explain the variation in the presented results.

As expected and described by several authors (Atangana et al. 2014; Ramachandran 1993) agroforests had a higher wild animals species diversity than farms working with conventional agriculture (see *Figure 5*). The most important difference between agroforest systems and conventional agriculture was the presence of large mammals. Large mammals were 44% more frequent in agroforest systems than in conventional agriculture (see *Figure 5*). Additionally, most farmers (93% agroforestry and 87% conventional agriculture) like having wild animals on their lands. This is an important positive aspect if agroforests will be used as part of a wider biodiversity conservation strategy. It is again important to point out that the mentioned results do not speak in favor of converting natural forests to agroforests for biodiversity conservation, but rather these results provide a basis for showing the potential that certain agroforest systems (the ones with low management intensity and high canopy connectivity (Cassano et al. 2014)) can have for serving as buffer zones or biological corridors. Moreover, the most often mentioned reason why farmers liked animals was simply because they felt that animals have also the right to live on their lands and it was “beautiful” (according to the farmers) to see them in their farms. Most of the few farmers that did not like wild animals in their lands mentioned that it was because they damaged their crops or livestock.

The following subsections are related to the second & third research questions

First, it is important to emphasize that I used the following specific criteria (mentioned in the methods section) for answering the second research question:

A) Is it economically viable to use agroforest systems – more profitable than other land uses (such as pasture with livestock or monocultures)?

B) How are the available support mechanisms (such as support programs, practical knowledge and examples of the region, monetary incentives, or loans) used for promoting agroforest systems?

C) What are the risks and disadvantages associated to the implementation of agroforest systems?

Comparing the economics of agroforest systems and conventional agriculture

The information provided by the farmers showed that the average monthly income per hectare during 2015 to 2017 for agroforestry farmers was of **245 R$** [standard error of the mean=51 R$, median=133 R$] and for conventional agriculture farmers it was **568 R$** [standard error of the mean=152 R$, median=233 R$]. Thus, according to these results conventional agriculture farmers would be earning more than twice as much income per hectare than farmers working with agroforestry in the Bahia SR. However, these results contradict the number one mentioned reason of why the analyzed farmers work with agroforestry. Around 90% of the farmers working with agroforests expressed that one of the main reasons and benefits of working with agroforest systems is the higher income generation (*Figure 9*). It is also important to point out that in *Figure 8* the farmers working with agroforestry perceived more economic benefits when intercropping with woody perennials than conventional agriculture farmers.

This contradictory information could have different explanations. First, it is important to remember that there are several different types of farms in this study, thus for making a more precise economical comparison one would have to narrow the number of species and system structure that would be analyzed. It would also be important to categorize the farms according to their species and structural composition, so it would be easier to see exactly which "type" of farm generates how much revenues. Moreover, in the questionnaires the farmers provided information just related to the income per hectare. The labor and material inputs where not analyzed in this study.

Another possible explanation for the big difference between the income of conventional agriculture farmers and agroforestry farmers is that most farmers working with agroforestry live in the state of Bahia and most farmers working with conventional agriculture live in the state of Minas Gerais (the distribution of the questionnaires according to each state and "farmer category" can be found in the *Methods-Analysis of the results* subsection). According to the organization working in Bahia (*Povos da Mata*), in 2016 the region experienced the hardest drought from the last 30 years. This organization pointed out that the drought in 2016 affected all the crops, according to the organization the agroforest systems that worked with tree species were affected the most. There was a big drought in Minas Gerais in 2015, but according to the contact organization in Minas Gerais (*Iracambi*) the farms were not really influenced by that drought.

Contrary to this study, other studies in Brazil show that agroforest systems can generate much higher revenues than conventional agriculture. For example a study carried out in the "Zona da Mata" in Minas Gerais (the same region where the farmers from Minas Gerais that took part in this study work) performed an economic comparison between agroforestry coffee and sun coffee plots (Souza et al. 2012). Souza et al. (2012) concluded that over a period of 12 years agroforestry coffee was more profitable than sun coffee due to the production of diversified agricultural goods, in spite of the higher establishment costs for agroforestry coffee. Another study conducted by Yamada & Gholz (2002) in the Brazilian Amazon (in the state of Pará) compared the yield of a variety of agroforest systems developed by local farmers of Japanese descent with the yield of local pasture, in other words cattle production. Yamada & Gholz (2002) showed that agroforest systems of 10 to 20 ha size yielded incomes comparable to 400 to 1200 ha pastures. Additionally, these agroforest systems generated substantially more rural employment per ha than the local pastures (Yamada & Gholz 2002).

To conclude, farms working with conventional agriculture yielded more than twice as much income per hectare than the analyzed agroforest systems. However, agroforest systems can generate a higher income than conventional agriculture according to the answers of the farmers in *Figure 9* and the two examples of economic analysis of agroforest systems in Brazil mentioned above (Souza et al. 2012, Yamada & Gholz 2002). It is not possible to generalize and state that agroforest systems or conventional agriculture yield higher incomes than the other farming system. How profitable an agroforest system or a conventional agriculture farm can be is context dependent and factors such as species in the system, labor and material inputs, market prices, certification mechanisms, and climatic or biological stress and/or disturbance will affect the income generated by the farms.

Awareness of and participation in governmental support programs

The payment for ecosystem services (PES) through the Atlantic Forest Law is the support program with least recognition and participation (*Figures 6 and 7*). Expanding programs such as the PES of the Atlantic Forest Law could encourage more farmers to use more sustainable and environmentally friendly farming practices such as the implementation of native trees on their lands and reducing the management intensity. Subsidies such as the PES could further improve the profitability of “biodiversity friendly” agroforest systems. In other regions of the world it has been shown that farmers participation in agroforestry practices can increase with effective PES programs. For example, Cole (2010) investigated the effects of PES related to the adoption of agroforestry systems and the planting of trees in southern Costa Rica. Cole (2010) showed that the farmers who took part of the PES program planted substantially more trees and more species than non-participant farmers. The PES program in southern Cost Rica helped farmers in overcoming initial economic and technical obstacles that made the adoption of agroforestry practices unattractive (Cole 2010). Finally, Cole (2010) recommends additional investment in short- to medium-term technical support for broad retention of agroforestry practices beyond the life of the PES contracts.

Farmers perceptions of agroforestry and how to increase conventional farmers willingness for agroforestry

In the results section, *Figure 8* shows what agroforestry and conventional agriculture farmers think about intercropping with woody perennials, and *Figure 9* and *10* show what agroforestry and conventional agriculture farmers perceive as the main reasons and limitations related to working with agroforestry. The most important findings to point out of these results are the following: Agroforestry farmers linked much more benefits related to working with agroforestry than conventional agriculture farmers (*Figure 9*). The three main benefits or reasons why agroforestry farmers work with agroforests are: a higher income generation (89%), the diversification of the production system (86%), and an increase in the land's quality and productivity (86%) (*Figure 9*). The three most important limitations for conventional agriculture farmers to switch to agroforestry systems are the uncertainty if the system will work (62%), the reduction in yield of the main agricultural crop (43%) and the lack of models and knowledge in the region (41%) (*Figure 10*).

Figure 10 shows that an effective way for increasing farmers willingness for agroforestry would be to increase the technical assistance, rural extension, and capacitation/training in agroforestry practices. If there are more successful models and research into the practical implementation of agroforest systems in this region farmers would be more willing to shift to or diversify to agroforest systems. *Figure 10* shows that two out of the three most important limitations (the system might fail, and lack of successful models and knowledge in the region) can be decreased by successful examples of agroforest systems in the region and training in how to create these systems. *Figure 9* shows that conventional agriculture farmers link many benefits to intercropping with woody perennials and almost half of the conventional agriculture farmers link it to a higher income generation. Moreover, 55% of the conventional agriculture farmers expressed that they would like to (in other words they would seriously consider) intercrop woody perennials in their lands (in other words shift to or diversify with agroforest systems). Providing successful agroforestry models, research into its application and practical knowledge into how to create these systems could thus substantially increase the number of conventional agriculture farmers that would be willing to shift to agroforest systems. Additionally, promoting PES such as the expansion of the program of the PES of the Atlantic Forest Law would further motivate farmers to implement “biodiversity friendly” agroforest systems. Cole (2010) while studying the effects of PES programs on the implementation of agroforest systems in southern Costa Rica also recommended the use of PES for motivating farmers to implement agroforestry systems, especially for overcoming the initial economic and technical obstacles. Additionally, Cole (2010) came to the same conclusions as this paper and suggested additional technical support for retaining agroforestry practices in the long term (beyond the life of PES contracts for example).

Especially agroforestry farmers, but also conventional agriculture farmers link more benefits than drawbacks in working with agroforestry/intercropping with woody perennials (see *Figures 8, 9* and *10*). Agroforestry and conventional agriculture farmers may value some benefits or limitations more than others, and thus according to the different expected benefits and drawbacks they chose the farming systems that suits their needs or expectations the best. It is also important to point out that *Figures 8, 9* and *10* show what farmers perceive about intercropping with woody perennials, and their perceptions of the main benefits and drawbacks of working with agroforest systems. This means that the perceptions of the farmers do not necessarily reflect all the reality, for example the contradiction found that the farmers working with conventional agriculture in this study actually generate more profits per hectare than the farmers working with agroecology. However, what farmers perceive as the main benefits or drawbacks of choosing one system or another plays a very important role in their decisions of which system they will choose to apply. Finally, the knowledge and perceptions of the farmers in this region (presented in the results) is of incredible value, because the “local” knowledge opens paths and information that may be overlooked by “top-down” approaches or other scientific literature.

Conclusions

According to the literature review, the analyzed species that use agroforest systems the most in southern Bahia is the GHLT, followed by the maned sloth and occasionally used by the GBC (Cassano et al. 2009; Cassano et al. 2012; Cassano et al. 2014). According to the farmers living in southern Bahia, the maned sloth was the most commonly found species in their agroforest systems (out of the three analyzed species, *Figure 4*). Moreover, *Figure 5* shows that agroforests contain a higher number of species than conventional agriculture farms in each animal species category, especially regarding large mammals. These results show that agroforests in the Atlantic Forest have the potential to serve as buffer zones or ecological corridors. Agroforests can have a high biodiversity conservation value if there is: no hunting pressure, no presence of domestic dogs, high canopy connectivity, species and structural composition similar to native forests, and close proximity to forest remnants. It is important to point out that agroforests do not replace the biodiversity conservation value of natural forests, however they can under certain circumstances serve as part of a wider biodiversity conservation plan.

Agroforestry farmers perceived much more benefits of working with agroforestry than conventional agriculture farmers (*Figure 9*). The number one reason of why agroforestry farmers worked with agroforestry was that it generates a higher income than conventional agriculture (89% mentioned this reason). However, in contradiction to what the agroforestry farmers expressed related to the higher profitability of agroforests, the results showed that the average monthly income per hectare of conventional agriculture farmers (575R$) was more than twice as much than the one of agroforestry farmers (246R$). The reasons behind this contradictory information can have several explanations, such as: the not clear enough differentiation between agroforests and conventional agriculture, most answers of conventional agriculture come from one region and most answers of agroforestry come from another one, or/and the lack of information regarding other important factors for measuring the profitability of a farm (such as the labor and material inputs). Thus, this research concludes that it is not possible to generalize and state that agroforest systems or conventional agriculture yield higher profits than the other farming system. How profitable a farm can be is context dependent and it depends on many factors that go beyond the classification of the farm as “agroforestry” or “conventional agriculture”.

More than half (55%) of the conventional agriculture farmers expressed that they would consider intercropping woody perennials in their lands. However, the three main limitations for conventional agriculture farmers to start intercropping woody perennials are: uncertainty if the system will work (mentioned by 62% of the respondents), the reduction in yield of the main agricultural crop (43%) and the lack of models and knowledge in the region (41%) (*Figure 10*). Thus, an important factor for increasing farmers willingness for agroforestry would be to increase the technical assistance, rural extension, and capacitation/training in agroforestry practices. With an easier access to these tools, farmers would have less uncertainty whether the agroforest systems will work. Additionally, a growing number of successful agroforestry examples would further facilitate the opportunities for farmers to implement this kind of systems. Expanding and including more farmers into programs such as the current PES of the Atlantic Forest Law could further promote the use of sustainable farming practices, especially PES could help in overcoming the initial economic obstacles related to the creation of agroforest systems (Cole 2010).

The literature review in this research showed that there are several studies that investigated the relation between agroforestry (especially shaded cocoa plantations) and biodiversity in the Bahia SR. However, there were very few studies that investigated the social and economic motivations and limitations related to agroforestry in the Atlantic Forest. This research shared insights into what are the reasons and drawbacks for agroforestry farmers and conventional agriculture farmers to implement agroforest systems. Nevertheless, the economic analysis realized on the farms on this study analyzed only the income per hectare of the farm and this approach had its limitations. Future research should focus on providing a more comprehensive economic analysis of agroforest systems and conventional agriculture farms working within the same frame; such as the same region, similar soils, similar species composition, clear distinction between agroforests and conventional agriculture.

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Appendix I - Questionnaire for farmers working with conventional agriculture and agroforestry

Questionnaire

Dear Sir or Madam, thank you for agreeing in taking part on this research questionnaire. My name is Mauricio Sagastuy. I am a student at the Gothenburg University in Sweden. 3 years ago, I had the opportunity to work in a rainforest reserve in southern Bahia. This experience triggered my interest and devotion to sustainable land use practices in the Atlantic Forest of Brazil. This questionnaire is the essence of my Master thesis. In my research project I aim to answer two questions for the north-eastern Atlantic Forest biome: first, to what extent can agroforest systems provide habitat for key animal species? And second, what are the motivations and limiting factors for family farmers to create agroforest systems? With this questionnaire I want to hear directly from the farmers their experiences and thoughts related to subjects about conventional agriculture and agroforestry. Therefore, with the data given to me in the questionnaire, I will be able to answer the second question of my research project.

The participation in this questionnaire is entirely voluntary and you are not obliged to answer these or any question if you don´t want to or feel uncomfortable with it. All the information will be used for non-commercial purposes. Also, be assured that the information you provide will be kept in the strictest confidentiality and will be kept anonymous. This questionnaire should only take 15 minutes to complete.

INFORMATION ABOUT THE FARM AND THE CURRENT PRACTICES (FOR BOTH KIND OF FARMERS)

Please fill in the information below and check with an X the boxes that are correct/fit to you and your farm. You can check more than one box per question

Which of these organizations provided you the questionnaire?

- ☐ Povos da Mata
- ☐ INCAPER
- ☐ Iracambi

A) General information about the farm:

- Name of the owner: ____
- Name of the farm: ____
- Location (state and municipality): ____
- Size of the farm (in ha): ____________________
- Area used for agricultural/agroforestry purposes in your farm (in ha): ________________
- How far is your farm to the next road (in meters or kms): _______________

- How far is your farm to the closest “primary or secondary forest” (in meters or kms) ___________________________

- Do you have an area where you plant products for your own/family consumption?
  - ☐ Yes
  - ☐ No
- Mention the plant and animal species on your agricultural land (excluding the land you use for own consumption). In other words, mention the species/products you sell/use for commerce.
  (*It can be that you work with just one or that you work with more species*):

1.
2.
3.
4.
5.
6.
7.
8.
9.
10.

B) Socio-environmental data:
- Do you consider your soil fertile?
  - ☐ yes
  - ☐ no
- Do you irrigate your land?
  - ☐ Yes
  - ☐ No
- Do you take or took part in any of the following support programs?
  - ☐ Technical assistance and rural extension
  - ☐ Capacitation/training for your current agricultural practice
  - ☐ I am part of an agricultural/agroecological organization, institution or support group

C) Income per hectare in the last 3 years:

- What was approximately your monthly income per hectare in the last 3 years (in Brazilian reals) If you know the information just for some of the years you can write that down too:

Year	Monthly income per hectare
2017	
2016	
2015	

QUESTIONS FOR BOTH KIND OF FARMERS

Questions about governmental programs that can support the creation of agroforest or agricultural systems

1. **Do you know of the existence of any of the following governmental programs that promote or can support the creation of agricultural or agroecological systems?**
   If yes, please mark the programs that you are aware of.

☐ Programa Nacional de Alimentação Escolar - PNAE
☐ Programa de Aquisição de Alimentos - PAA
☐ PRONAF - Programa Nacional da Agricultura Familiar
☐ Payment for ecosystem services -Atlantic Forest Law
☐ Other governmental programs: ____

2. **Do you take or took part in any of the following governmental programs?**
   Please mark the programs you take or took part of.

☐ Programa Nacional de Alimentação Escolar - PNAE
☐ Programa de Aquisição de Alimentos - PAA
☐ PRONAF - Programa Nacional da Agricultura Familiar
☐ Payment for ecosystem services -Atlantic Forest Law
☐ Other governmental programs: ____

Questions about the acceptance of wild animals

3. **Do some of the wild animals listed below come through or live on your land?**
   If yes, please mark the animals that come through or live in your land.
   - ☐ Maned sloth (just for the farmers living in southern Bahia)
   - ☐ Golden-headed-lion tamarin (just for the farmers living in southern Bahia)
   - ☐ Golden-bellied capuchin (just for the farmers living in southern Bahia)
   - ☐ Other monkeys
   - ☐ Carnivores (such as oncilla, ocelot, crab-eating fox, and other carnivores)
   - ☐ Other large mammals (such as peccary, deer)
   - ☐ Rodents (such as mice, squirrel, bristle-spined rat and other rodents)
   - ☐ Bats

4. **Do you accept/like having wild animals on your land (such as monkeys, small or large rodents, foxes, armadillos, and other small or large animals)?**
   - ☐ Yes
   - ☐ No

   2.1 If your answer was <u>yes</u>, what are the reasons for you to accept/like having these wild animals in your land??

   - ☐ They can act as "regulators" on my land and thus avoid biological diseases/ making my system more resilient
   - ☐ Animals have a right to live here too
   - ☐ I can hunt them and use as food source
   - ☐ Other: ____

   2.2 If your answer was <u>no</u>, what are the reasons for you not to accept/like having these wild animals on your fields?

   - ☐ They can damage my crops/domesticated animals
   - ☐ They can damage my household and the items in it (such as food, pets, etc.)
   - ☐ They can bring pests and diseases to the land
   - ☐ Other: ____

Questions about intercropping and agroforestry

5. **What do you think/is your perception about intercropping woody perennials with your main agricultural crop?**
Please mark with an X, the answers that you agree with:

- ☐ It can decrease the income and the production of the land in the short term
- ☐ It can decrease the income and the production of the land in the long term

- ☐ It can increase the income and the production of the land in the short term
- ☐ It can increase the income and the production of the land in the long term

- ☐ It can bring more pests and diseases to the system
- ☐ It can attract natural enemies and regulate the microclimate, avoiding pests and diseases in the system
- ☐ It can increase the quality and nutrients in the soils
- ☐ It can make the system more resilient towards market changes
- ☐ It is more complicated to sell/ make profits out of two or more different products
- ☐ It can complicate my production system
- ☐ I don’t have experience with it and I can be risking my income

QUESTIONS JUST FOR FARMERS THAT WORK WITH AGROFOREST SYSTEMS

6. **What are the main reasons for you to work with agroforest systems compared to conventional/monoculture farming system? Which benefits do you get from practicing this land-use system?**
Please mark with an X the main reasons:

- ☐ Higher income generation
- ☐ The ability to sell the products at a higher unit price/price per kg (due to its organic origins, better quality of the products or different certification mechanisms)
- ☐ Increases the land´s quality and productivity (water retention, improvement of the soils, use of different levels of production, microclimate regulation, etc.)
- ☐ A system that can give you different products at different times of the year
- ☐ More products and food for self sufficiency
- ☐ Agricultural system that is more resilient to climatic, biological (diseases) or market impairs
- ☐ It helps in conserving/increasing the biodiversity of flora and fauna in the region
- ☐ Other important reasons: ____

7. **What are the disadvantages/most limiting factors when working with agroforest systems?**
   Please mark with an X the main disadvantages/limiting factors:

☐ The long time one has to wait to make profits out of the woody perennials
☐ Reduction in yield of the main agricultural crop
☐ The logistical difficulty of managing and harvesting two (or more) plant species in the same area
☐ The difficulty to sell diverse products in the market
☐ Uncertainty towards the rights to own the land in the long term
☐ It attracts unwanted pests, insects, animals or other biological diseases
☐ Other important disadvantages/limitations: ________________________________

QUESTIONS JUST FOR FARMERS THAT DON'T WORK WITH AGROFOREST SYSTEMS

8. **If you could plant more woody perennials (such as trees, shrubs, palms, bamboos, etc.) in your field and thus potentially get benefits from this diversified agricultural system, but you would also be taking a risk in changing the dynamics of your land, would you consider implementing this kind of system?**

☐ Yes
☐ No

8.1 If your answer was yes, which benefits would you be expecting to get from your farm diversified with woody perennials (such as trees, shrubs, palms, bamboos, etc.)?
Please mark with an X the main expected benefits:

☐ Higher income generation
☐ The ability to sell the products at a higher unit price/price per kg (due to its organic origins, better quality or different certification mechanisms)
☐ Increases the land´s quality and productivity (water retention, improvement of the soils, use of different levels of production, microclimate regulation, etc.)
☐ A system that can give you different products at different times of the year
☐ More products and food for self sufficiency
☐ Agricultural system that is more resilient to climatic, biological (diseases) or market impairs
☐ It helps in conserving/increasing the biodiversity of flora and fauna in the region
☐ Other important reasons: ____

8.2 If your answer was <u>yes</u>, what do you think are the main barriers for diversifying your farm with woody perennials?
Please mark with an X the main barriers:

☐ Uncertainty towards how the system might work/it might fail
☐ Lack of successful models and knowledge in the region where I live to know how to make that transition
☐ The long time one has to wait to make profits out of the woody perennials
☐ Reduction in yield of the main agricultural crop
☐ The logistical difficulty of managing and harvesting two (or more) plant species in the same area
☐ The difficulty to sell diverse products in the market
☐ Uncertainty towards the rights to own the land in the long term
☐ It might attract unwanted pests, insects, animals or other biological diseases
☐ Other important disadvantages/limitations: ________________________________

8.3 If your answer was <u>no</u>, what are the main reasons why you would not like to implement woody perennials in your farm?
Please mark with an X the main reasons:

☐ Uncertainty towards how the system might work/it might fail
☐ Lack of successful models and knowledge in the region where I live to know how to make that transition
☐ The long time one has to wait to make profits out of the woody perennials
☐ Reduction in yield of the main agricultural crop
☐ The logistical difficulty of managing and harvesting two (or more) plant species in the same area
☐ The difficulty to sell diverse products in the market
☐ Uncertainty towards the rights to own the land in the long term
☐ It might attract unwanted pests, insects, animals or other biological diseases
☐ Other important disadvantages/limitations: ________________________________

Appendix II – List of the studies used for each species in the bibliographical research

Golden-headed Lion Tamarin – 11 studies

Almeida R.; Vleeschouwer, K.; Reis, P (2015): Do Habitat Use and Interspecific Association Reflect Predation Risk for the Golden-Headed Lion Tamarin (Leontopithecus chrysomelas)? In Int J Primatol 36 (6), pp. 1198–1215. DOI: 10.1007/s10764-015-9885-6.

Cassano, C.; Barlow, J.; Pardini, R. (2012): Large Mammals in an Agroforestry Mosaic in the Brazilian Atlantic Forest. In Biotropica 44 (6), pp. 818–825. DOI: 10.1111/j.1744-7429.2012.00870.x.

Cassano, C.; Schroth, G.; Faria, D.; Delabie, J.; Bede, L. (2009): Landscape and farm scale management to enhance biodiversity conservation in the cocoa producing region of southern Bahia, Brazil. In Biodivers Conserv 18 (3), pp. 577–603. DOI: 10.1007/s10531-008-9526-x.

Cassano, C.; Barlow, J.; Pardini, R. (2014): Forest loss or management intensification? Identifying causes of mammal decline in cacao agroforests. In Biological Conservation 169, pp. 14–22. DOI: 10.1016/j.biocon.2013.10.006.

Catenacci, L.; Pessoa, M.; Nogueira-Filho, S.; Vleeschouwer, K. (2016): Diet and Feeding Behavior of Leontopithecus chrysomelas (Callitrichidae) in Degraded Areas of the Atlantic Forest of South-Bahia, Brazil. In Int J Primatol 37 (2), pp. 136–157. DOI: 10.1007/s10764-016-9889-x.

Oliveira, L.; Hankerson, S.; Dietz, J.; Raboy, B. (2010): Key tree species for the golden-headed lion tamarin and implications for shade-cocoa management in southern Bahia, Brazil. In Animal Conservation 13 (1), pp. 60–70. DOI: 10.1111/j.1469-1795.2009.00296.x.

Oliveira, L.; Dietz, J. (2011): Predation Risk and the Interspecific Association of Two Brazilian Atlantic Forest Primates in Cabruca Agroforest.

Oliveira, L.; Neves, L.; Raboy, B.; Dietz, J. (2011): Abundance of jackfruit (Artocarpus heterophyllus) affects group characteristics and use of space by golden-headed lion tamarins (Leontopithecus chrysomelas) in Cabruca agroforest. In Environmental management 48 (2), pp. 248–262. DOI: 10.1007/s00267-010-9582-3.

Raboy, B.; Christman, M.; Dietz, J. (2004): The use of degraded and shade cocoa forests by Endangered golden-headed lion tamarins Leontopithecus chrysomelas. In ORX 38 (01). DOI: 10.1017/S0030605304000122.

Raboy, B.; Neves, L.; Zeigler, S.; Saraiva, N..; Cardoso, N.; dos Santos, G. et al. (2010): Strength of Habitat and Landscape Metrics in Predicting Golden-Headed Lion Tamarin Presence or Absence in Forest Patches in Southern Bahia, Brazil. In Biotropica 42 (3), pp. 388–397. DOI: 10.1111/j.1744-7429.2009.00595.x.

Tisovec, K.; Cassano, C.; Boubli, J.; Pardini, R. (2014): Mixed-species Groups of Marmosets and Tamarins Across a Gradient of Agroforestry Intensification. In Biotropica 46 (2), pp. 248–255. DOI: 10.1111/btp.12098.

Maned sloth – 6 studies

Cassano, C.; Barlow, J.; Pardini, R. (2012): Large Mammals in an Agroforestry Mosaic in the Brazilian Atlantic Forest. In Biotropica 44 (6), pp. 818–825. DOI: 10.1111/j.1744-7429.2012.00870.x.

Cassano, C.; Schroth, G.; Faria, D.; Delabie, J.; Bede, L. (2009): Landscape and farm scale management to enhance biodiversity conservation in the cocoa producing region of southern Bahia, Brazil. In Biodivers Conserv 18 (3), pp. 577–603. DOI: 10.1007/s10531-008-9526-x.

Cassano, C.; Kierulff, M.; Chiarello, A. (2011): The cacao agroforests of the Brazilian Atlantic forest as habitat for the endangered maned sloth Bradypus torquatus. In Mammalian Biology - Zeitschrift für Säugetierkunde 76 (3), pp. 243–250. DOI: 10.1016/j.mambio.2010.06.008.

Chiarello, A. (1998): Effects of fragmentation of the Atlantic forest on mammal communities in south-eastern Brazil.

Falconi, N.; Vieira, E.; Baumgarten, J.; Faria, D.; Fernandez G., Gastón A. (2015): The home range and multi-scale habitat selection of the threatened maned three-toed sloth (Bradypus torquatus). In Mammalian Biology - Zeitschrift für Säugetierkunde 80 (5), pp. 431–439. DOI: 10.1016/j.mambio.2015.01.009.

Santos, P.; Chiarello, A.; Ribeiro, M.; Ribeiro, J.; Paglia, A. (2016): Local and landscape influences on the habitat occupancy of the endangered maned sloth Bradypus torquatus within fragmented landscapes. In Mammalian Biology - Zeitschrift für Säugetierkunde 81 (5), pp. 447–454. DOI: 10.1016/j.mambio.2016.06.003.

Golden-bellied capuchin – 4 studies

Canale, G.; Kierulff, M.; Chivers, D. (2013): A Critically Endangered Capuchin Monkey (Sapajus xanthosternos) Living in a Highly Fragmented Hotspot. In Laura K. Marsh, Colin A. Chapman (Eds.): Primates in Fragments. New York, NY: Springer New York, pp. 299–311.

Canale, G.; Suscke, P.; Rocha-Santos, L.; Bernardo, C.; Martins K.; Chivers, D. (2016): Seed Dispersal of Threatened Tree Species by a Critically Endangered Primate in a Brazilian Hotspot. In Folia primatologica; international journal of primatology 87 (3), pp. 123–140. DOI: 10.1159/000447712.

Cassano, C.; Barlow, J.; Pardini, R. (2014): Forest loss or management intensification? Identifying causes of mammal decline in cacao agroforests. In Biological Conservation 169, pp. 14–22. DOI: 10.1016/j.biocon.2013.10.006.

Flesher, K. (2015): The Distribution, Habitat Use, and Conservation Status of Three Atlantic Forest Monkeys (Sapajus xanthosternos, Callicebus melanochir, Callithrix sp.) in an Agroforestry/Forest Mosaic in Southern Bahia, Brazil. In Int J Primatol 36 (6), pp. 1172–1197. DOI: 10.1007/s10764-015-9884-7.