Agroforestry Systems on Brazilian Legal Protected Lands: Permanent Preservation Areas (PPA) and Legal Reservation Areas (LRA)

ABSTRACT

Forests preservation and restoration are crucial, to sustain ecological and social benefits. However, forest lands have been reducing around the world. In the context of forest restoration, agroforestry systems are important land use instruments, because they allow food production combined with sustainable forest management. There are different kinds of agroforestry systems, and they can occur in degraded areas and also in forested areas which are legally protected or not. In Brazil, where forests cover 46.5% of land area, deforestation continues and there are several challenges to protect and restore forests. In this case, it is necessary to advance sustainable forest management to protect the remaining forests, to restore forest lands and to permit uses which contribute to Brazilian society, especially to the campesinos. *Permanent Preservation Areas (PPA)* and *Legal Reservation Areas (LRA)*, which have been institutionalized in Brazilian Environmental Legislation require the maintenance of areas with native vegetation within rural properties restricting certain activities, accordingly with this understanding, the legislation limits the possibility of obtaining income from agricultural activities. Historically, they have not been duly respected by most landowners where riverbanks, springs, slopes and other areas that should be preserved have been occupied suppressing natural vegetation. Thus, there are possibilities for ecological management and use of protected areas, specifically *PPA* and mainly *LRA*, which seek to both preserve environmental resources and contribute to food production and income, especially in the campesino smallholders. This paper discusses possibilities and limitations of using agroforestry systems in PPA and LRA, pointing out that agroforestry systems are also feasible for restoring degraded areas and for expanding enriched areas and uses of their natural resources. Despite legal possibilities, a historical problem in Brazil is related to the lack of compliance with environmental legislation. Moreover, in actuality the scenario of deforestation and several difficulties to advance in environmental management in Brazil have been harming this conservationist possibilities. There is much to be done to facilitate the expansion of agroforestry systems, such as investments in research, extension and public policies that provide grants and loans for this kind of management.

Keywords: Forest Legislation. Deforestation. Agroforestry for Environmental Objectives. Biodiversity.

1 Introduction

Certain human activities such as wood extraction, agriculture, forestry and intensive livestock raising, in addition to urban sprawl and industrialization, have been responsible for reducing natural forest cover around the world. These processes lead to harmful consequences for the dynamics of ecosystems, including the loss of biodiversity (plant and animal), erosion and loss of soil fertility, silting of watercourses, etc.

To decrease these problems, Environmental Legislation aims to regulate the land use and occupation, especially regarding the institution of rights and duties/obligations related to natural resources. In Brazil, the natural environment is considered a good of common use (Milaré, 2007).

The Brazilian Environmental Legislation, specifically from 1965 through Law 4,771/65, requires the maintenance of areas with native vegetation within rural properties, by the following legal mechanisms: the *Permanent Preservation Areas (PPA)* and *the Legal Reservation Areas (LRA)*. These two legal figures restrict certain activities to favor environmental preservation and conservation. History tells us, these areas have not been properly respected by some rural property owners, as well as by the government in the process of rural and urban engagement. Thus, riverbanks, springs, slopes and other areas that should be preserved have been absorbed, suppressing natural vegetation in all Brazilian biomes and ecosystems.

To the present date, many lands that should be destined for PPA and LRA continue to be cleared, because farmers consider the legislation useless or unnecessary. Understanding that these areas limit the possibility of obtaining income, most Brazilian farmers oppose the requirements of forest legislation. Although, there are legal possibilities for the management and use of PPA and mainly of LRA, which can contribute to farmers' food and income, especially those that have smallholdings, called "small property" or "family rural tenure" in Brazilian legislation (Law 12,651/2012). Among these alternatives agroforestry systems stand out.

> Agroforestry is a collective name for land-use systems in which woody perennials (trees, shrubs, etc.) are grown in association with herbaceous plants (crops, pastures) or livestock, in a spatial arrangement a rotation, or both; there are usually both ecological and economic interactions between the trees and other components of the system. (Lundgren, 1982: 3).

In a global context where agriculture demands much of natural resources, such as water and soil, environmental impacts (deforestation, biodiversity loss, etc.) occur and

contribute to environmental contamination (with wide pesticides and fertilizers use) it is necessary to create and implement sustainable land use strategies. In this perspective, agroforestry systems, mainly agroecological and diversified are an important example.

Food and Agriculture Organization (FAO) of the United Nations (UN) points out that agroforestry is crucial to smallholder farmers and other rural people because it can enhance their food supply income and health.[1]

Despite the different agroforestry systems, from the simplest (for economic purposes) to the most complex (which in addition to production, aim to conserve the forest with native species) (Miller, 2009), they are, generally, understood in Brazilian law as agroforestry systems (SAF) (Brazil, 2009 and 2012) or agroforestry and *agrossilvipastoril*[2] systems (Brazil, 2012).

Considering a historic process of inadequate land settlement in Brazil where forests and other natural vegetation have been suppressed for agriculture, pastural, and other uses, discuss and present actions which combine food production and biodiversity restoration, like agroecological agroforestry systems is very important.

By the provisions of Law 12,651/2012, which instituted the "new" Brazilian Forest Code, in Resolutions 369/2006, 425/2010 and 429/2011 of the National Council of the Environment (CONAMA) and in Normative Instruction 5/2009 of the Ministry of the Environment, we sought to analyze in what sense agroforestry systems have been covered in Brazilian legislation to discuss how agroforestry systems can be implemented in areas of LRA and PPA.

The methods of this article utilized literature about land and forestry management systems (concept, basic principles, kinds), highlighting the difference between simple and diversified/agroecological systems; an analysis of the legislative tools that govern forest protection in Brazil, especially Law 12,651/2012; data of forest cover and deforestation in Brazil (supplementary file); and results and conclusions from similar literature which analyzed questions related to agroforestry systems in the country. With this information, we have discussed possibilities of agroforestry management in PPA and LRA, reflecting about difficulties and challenges for expansion of agroforestry systems in Brazil.

[1] Available at <http://www.fao.org/forestry/agroforestry/80338/en/>.
[2] The word *agrossilvipastoril* means a combination of agriculture, planted trees and pasture land use.

The article is structured in four sections and a supplementary file beyond introduction and conclusion. The supplementary file provides data about world forest configuration and deforestation, to highlight the importance of Brazilian forests.

Section 1: provides an overview of the topics of the article. Section 2: discusses briefly agroforestry systems basic principles in the context of sustainable forest management. Section 3: presents elements of Brazilian forest legislation foremost PPA and LRA. Section 4: argues the possibilities of agroforestry use in PPA and LRA considering Brazilian legislation. Section 5: discusses the feasibility and difficulties for applying agroforestry in PPA and LRA, considering actual challenges to advance in the accomplishments of environmental and forest legislation in Brazil. Section 6: provides a conclusion.

2 Agroforestry for Sustainable Forest Management

In the context of forest restoration, agroforestry systems are important land use tools because they allow food production (plants and animals) combined with forest rehabilitation and sustainable management. The goals, principles, history and kinds of agroforestry systems are discussed by international (Lundgren, 1982; De Jong et al., 2001; Mead, 2004; Roshetko et al., 2008; Smith, 2010; Umrani and Jain, 2010) and Brazilian authors (May and Trovatto, 2008; Deitenbach, 2008; Porro, 2009; Miller, 2009; Ewert et al., 2016).

> The term agroforestry is an "umbrella" term for those land-use practices and technologies where trees or other woody perennials are deliberately grown with crops, pastures or animals on farms. […] agroforestry as a dynamic, ecologically based, natural resource management system that, through the integration of trees on farms and in the agricultural landscape, diversifies and sustains production for increased social, economic and environmental benefits for land users at all levels. […] it is seen by many as a means of poverty alleviation, particularly for rural peoples. The scientific application is relatively new, although many of the practices are ancient. (Mead, 2004: 8).

Agroforest consists of land use that combines 'planted trees' with forest flora and fauna, either retained or naturally regenerated vegetation (De Jong et al., 2001), creating environmental, economic, and social benefits (USDA, 2019[3]).

[3] Available https://www.usda.gov/topics/forestry/agroforestry

Agroforestry is a productive and sustainable alternative for socioenvironmental contexts. They allow a dynamic and ecological management of natural resources, contributing to the maintenance of biodiversity and to the food and income of farming families (Porro, 2009).

> There is potential for an agroforestry ecosystem to move from a relatively simple one to one of greater complexity, which is akin to natural succession in forests. […] The three basic components of an agroforestry land-use system are the tree or woody perennial, the herbaceous component, and animals. Agroforestry systems must have trees and at least one of the other components. This is the basis of the classification into trees plus crops (agrisilvicultural), trees plus pastures and/or animals (silvopastoral), and trees plus crops and animals (agrosilvopastoral). (Mead, 2004: 11).

Agroforestry can contribute to reducing agriculture's vulnerability to climate change, improve water quality and availability among other services. It also can increase and diversify farmers' incomes, allow them to have access to more nutritious food and impel other social benefits. Because agroforestry integrates multiple natural components, it necessarily brings together people from diverse fields of knowledge. (FAO, 2015[4]).

"Tree planting in agroforests can occur in an open field stage, often in between food crops, or in small gaps or clearings in existing forest." (Roshetko et al., 2008: 466). Agroforestry can occur in degraded areas and in forested areas legally protected or not. For each area there are different kinds of agroforestry systems that can be applied according to farmer opposition and interest.

Roshetko et al. (2008) present four kinds of tree-based land use systems: 1) *Natural forests*; 2) *Sustainably Managed Forests*; 3) *Forest and Tree Plantations*, with a commercial goal and one or two planted species; and 4) *Smallholder Tree-Based Systems*. For the discussion in this paper, we will focus on *smallholder agroforestry systems* (4), understanding that this kind of land use is possible and viable in Brazilian protected areas, i.e., PPA and LRA, especially in "campesino"[5] properties.

Considering that smallholder tree-based systems play significant roles in the livelihoods of local communities it is important to 1) recognize the contribution and importance of smallholder agroforestry systems; 2) provide technical support; 3) adopt

[4] Available http://www.fao.org/forestry/agroforestry/80338/en/

[5] The term "campesino" refers to farmers who live and work in smallholders. It is a word from Spanish language which has been used in academic literature around the world. In Brazil, Law 11,326/2006 use the terms "family farmer" and "family agriculture".

holistic and sustainable strategies to support and strengthen the market orientation; 4) develop supportive institutions and policies (rules and organizations); 5) utilize enabling conditions that support the success of these systems (Roshetko et al., 2008).

According to Mead (2004: 10), "in both the developing and industrialized world, agroforestry is now accepted as an important land-use system, driven by the need to create sustainable and robust agroforestry ecosystems."

In Brazil, despite forest covering 46.5% of land area (Mapbiomas, 2021), deforestation continues and there are several challenges to forest protection and conservation. In this sense, it is necessary to advance sustainable strategies for forest management, to protect the forests and to permit uses which could contribute to Brazilian society, especially campesinos. In this context, complex agroforestry systems can play an important role to improve campesino lives.

Miller (2009) differentiates two major groups of agroforestry in Brazil: 1) based on an agroecological perspective, that seek to combine food production and restore forests with diverse native species and 2) agronomic and conventional systems, which are based on few species and seek to produce wood. The first works with dense planting, diversified species, rapid accumulation of organic matter, ecological and economic stability contributing to biodiversity. The second promotes lower density and diversification of species, few species and interactions, offering fewer products. In this sense, our focus is to discuss the possibilities of agroforest land use in PPA an LRA in smallholder are based on agroecological agroforestry systems.

The sequences in addressing this thesis are, the main Brazilian laws of forest protection, the definitions of PPA and LRA and the possibilities of management in these areas with agroecological agroforestry systems.

3 Brazilian Forest Legislation and Agroforestry in the Context

3.1 Background and Overview of Forest Protection

The legal instruments that direct the Legislation have different segments. No legal device can be above or contradictory to the content of the Federal Constitution. The Legislative Power is responsible for creating Laws, whether at the Federal (Chamber of

Deputies and Federal Senate), interstate (Legislative Assemblies) or Municipal (City Councils) levels[6].

To make some Law acceptable it is necessary to regulate it by Decrees, which are prepared by law-related agencies. The elaboration of a Decree by the Ministry of the Environment (ME), which is sanctioned by the President of the Republic, is essential to regulate a Law on the environment. Another legal tool is normative instructions (NIs), which details contents, administrative procedures and permitted and prohibited practices.

Other bodies with attributions in the environmental area are the Environmental Councils. The main Council at the Federal level is the National Council of the Environment (CONAMA). The states of the federation and municipalities must also have their Councils. The councils aim at expanding the participation of sectors involved with the environmental issue (public, private or social organizations).

Regarding forest protection standards, the first to be published in Brazil was in 1934, through Decree 23,793/34, which institutionalized the first Brazilian Forest Code. The main objective of the Decree was to order the exploitation of forest resources (Zakia and Derani, 2006).

In the 1960s, with the emergence of the ecological movement, new legislative texts were institutionalized to the prevention and control of environmental degradation[7], Forest Code (Law 4,771/65).

In 1965, through the enactment of Law 4,771, a new Forest Code was established in Brazil. Unlike the 1934 Code, which dealt with the protection of forests against the dilapidation of the country's forest cover, limiting individuals to the unrestricted power over rural properties the new text of 1965 had an interventionist state policy on private property. Forests came to be considered goods of common interest of the country (Laureano and Magellan, 2011).

The Forest Code of 1965 also established the *Permanent Preservation Area (PPA)* and the *Legal Reservation Area (LRA)*, which, although not properly delimited and maintained by most of landowners, constitute legal requirements to date. This Law could

[6] There are 27 states and 5,570 municipalities in Brazil.

[7] Other Laws in this context are the Land Statute (Law 4,504/64); the Wildlife Protection Act (Law 5,197/67); the Fishing Code (Decree 221/67); the Mining Code (Decree 227/67); and the National Basic Sanitation Policy (Decree 248/67) (Milaré, 2007).

have been a milestone for the effective protection of forests throughout Brazilian territory whether in rural or in urban areas.

If it had been fulfilled since 1965, the process of land use in Brazil would have taken place with more caution, protecting areas with greater environmental fragility (wetlands, areas with high slopes, refuges for plant and animal biodiversity). Though, the Law has not properly applied, generating problems that continue. The lack of adequate environmental management with guidance, inspection and enforcement of infractions has made this law ineffective.

Recently, Law 4,471/65 and other legislative tools[8], were repealed or amended with the new Forest Code, institutionalized through Law 12,651/2012. Considering the relevance of this Law, called "new Brazilian Forest Code" either as an incentive for conservation and forest preservation, or as a limiting factor in the expansion of agribusiness, it is worth mentioning that it was developed and approved after various debates between the "ruralist bench" (composed by politicians linked to agribusiness) and environmental groups in the country[9].

It indicates different intentions and territorialities, and despite the enactment of the Law, continue to exist. Although, the debates on Law 12,651/2012 lasted for months involving meetings, consultation with specialists and public hearings, environmentalists and many environmental and forestry researchers concluded that the agribusiness sector managed to press their interests on this law.

On the other hand, many argue that Law 12,651/2012 allowed the legal regularization of thousands of rural establishments, which were not in compliance with Law 4,471/65. Through the creation of "consolidated rural areas", Law 12,651/2012 made it possible to regularize construction and occupation of areas that should have been preserved. Still, it is necessary to consider why these establishments did not follow the provisions of the 1965 Law?

The Forest Code requires the maintenance/preservation of a portion of the rural property with existing native or secondary vegetation and if there is no such vegetation, forest regeneration within rural properties is necessary. The two legal figures of forest

[8] Laws 4,471/65, 7,754/89 and Provisional Measure 2,166-67/2001 have been repealed and Laws 6,938/81, 9,393/96, and 11,428/2006 have been amended.

[9] The debate about the construction process and the changes that occurred in the Forest Code promulgated in 2012 will not be addressed here. The documentary "The Law of Water", available in <https://www.youtube.com/watch?v=jgq_SXU1qzc> presents the main points that generated controversy in this context.

preservation/conservation are the so-called *Permanent Preservation Areas (PPA)* and the *Legal Reservation Areas (LRA)*. In them, especially in PPA activities are restricted. Even so, there are possibilities of conservation use in these areas.

These areas are similar, but have different usage and restrictions. They play important roles such as maintaining and/or restoring forest areas. Even though, PPA and LRA are the target of criticism from the agribusiness sector because they are seen as useless from an economic perspective.

Many farmers revolt against environmental laws without realizing that they fight against ecosystems, which have an immeasurable wealth and if properly managed, can bring environmental and economic benefits. In the midst of existing environmental conflicts related to compliance with environmental legislation, types of conservation use, such as agroforestry systems appear as a strategy for the environmental regularization of protected areas in rural properties, i.e., PPA and LRA (Meirelles, 2003).

3.2 Permanent Preservation Areas (PPA) and Legal Reservation Areas (LRA)

The concept of PPA was established in Law 4,771/65 and was not changed in the new Forest Code (Law 12,651/2012). It legally corresponds to a:

> protected area covered or not by native vegetation, with the environmental function of preserving water resources, landscape, geological stability, and biodiversity, facilitating the gene flow of fauna and flora, protecting the soil, and ensuring the well-being of human populations (Brazil, 2012, Article 3rd, III).

Unlike the LRA, which can be instituted in any portion of the rural property, PPA are delimited according to the relief and hydrography of the rural property.

PPA[10] are the marginal strips of any natural watercourse, from the edge of the regular watercourse bed, areas around the lakes and natural lagoons, the areas surrounding artificial water reservoirs resulting from impoundment or damming of natural watercourses […]; the areas around the springs […]; the slopes […] greater than 45°; the *restingas*[11]; the mangroves; the edges of the plateaus; on top of hills; and areas at an altitude greater than 1,800 meters (Brazil, 2012, Article 4h).

[10] Article 4th of Law 12,651/2012 provides in detail the delimitations corresponding to PPA (BRASIL, 2012).

[11] *Restinga* is a sandy deposit parallel to the coastline, generally elongated, produced by sedimentation processes, where different communities that receive marine influence are found, with mosaic vegetation cover, found on beaches, sandy ridges, dunes and depressions, presenting, according to the successional stage, herbaceous, shrubby and arboreal strata. (BRASIL, 2012, Article 3rd, XVI).

Considering that diverse ecosystems encompass PPA, agroforestry systems could be recommended for marginal strips of natural watercourses (Chart 1) and natural lagoons, areas surrounding artificial water reservoirs and slopes greater than 45°, only if these areas have been without natural vegetation.

Chart 1: Width of the Marginal Watercourse Range of the PPA

Width of Regular Watercourse (meters)	Marginal Band (meters)
Less than 10	30
10 to 50	50
50 to 200	100
200 to 600	200
Higher than 600	500

Source: Law 12,651/2012 Chapter II, Article 4th.

Yet, in the case of proof of the existence of "consolidated rural areas" in "small" properties (smaller than 4 fiscal modules[12]), the requirements in terms of the size of the marginal areas to the watercourses were reduced. Article 61-A of Law 12,651/2012 details this flexibilization.

As in the case of PPA, LRA was practically not changed in the current Forest Code (Law 12,651/2012). The LRA corresponds to an:

> area located within a property or rural property, delimited in accordance with art. 12, with the function of ensuring the sustainable economic use of the natural resources of the rural property, assisting the conservation and rehabilitation of ecological processes, and promoting the conservation of biodiversity, as well as the shelter and protection of wild fauna and native flora (Brazil, 2012, Article 3rd).

The LRA is a percentage of the rural property according to the total area of the property. Article 12 defines the percentage that each region needs to maintain in rural properties and this area can be delimited by the owner. This law establishes that "every rural property must maintain an area with native vegetation cover as a LRA, without prejudice to the application of the rules on PPA" (Brazil, 2012, Article 12).

Article 12 of Law 12,651/2012 provides the percentage that each region needs to maintain in rural properties with native vegetation as a LRA which are: I - located in the

[12] In Brazil, the size of a fiscal module in an agricultural establishment (farm) varies between municipalities, with the smallest being 50,000 m^2 and the largest being 1,100,000 m^2. Thus, the area of an establishment with up to 4 fiscal modules can reach 4,400,000 m^2.

Legal Amazon: a) 80% in the property located in forest area, b) 35% in the property located in Cerrado[13] area, c) 20% in the property located in general field area, II - located in the other regions of the country: 20% (Brazil, 2012, Article 12). Therefore, except for the Amazon Biome in the other Brazilian biomes, including the Atlantic Forest, it is required that 20% of each rural property be destined as LRA.

LRA is a portion of the rural property that must be destined to forest conservation (Delduque, 2008). If the area were preserved it can be maintained. If LRA were without natural vegetation or with some land use, legislation allows sustainable management, like agroforestry. Despite the priorities for the delimitation of LRA it is necessary to question if the criteria and studies to define the location of legal reservation areas, present in Article 14 of Law 12,651/2012, will be properly followed, and conducted.

LRA could be in strategic areas to contribute to ecological functions. It could improve ecological corridors for animals, linking PPA areas and rivers, establish tree barriers to reduce pesticide contamination, etc. Although the concept and dimensions of PPA and LRA have been maintained, Law 12,651/2012 relaxed some requirements for smallholders, as will be discussed in the next section.

3.3 PPA and LRA in Smallholders

In Brazil, the recognition of the need to decipher smallholders and large rural properties as well as campesinos and farmers with a capitalist and commercial profile, including big landowners, is recent. This kind of debate is wide and involve Brazilian agrarian problems.

Historically, benefits such as agricultural public policies and financing were restricted to large-scale farmers. A National Policy for campesino smallholders was created only in 2006 (Candiotto, 2011). According to Law 11,326/2006, which broaches the "National Policy on Family Agriculture and Rural Family Enterprises", to be considered a family farmer the following requirements should be met: 1) must not hold an area greater than 4 fiscal modules; 2) predominantly use his family's labor force in the economic activities of his establishment or enterprise; 3) have part of family income originated from economic activities of smallholder.

[13] Cerrado is one of the five major biomes in Brazil, which covered about 25% of Brazilian territory. It is similar to Savannah. More information is available at <https://www.icmbio.gov.br/cbc/conservacao-da-biodiversidade/biodiversidade.html>.

Law 12,651/2012 lessened some requirements for forest restoring for smallholders. In spite of that, according to Law 11,326/2006, any rural property that has a land area smaller than 4 fiscal modules can be a smallholder. But in Brazil, the area of a property with less than 4 fiscal modules can reach 4,400,000 m^2, i.e., 440 hectares. In this sense, in Brazil big areas can be legally accepted in the context of smallholder. For many experts it is a problem because large land areas can benefit from this loophole.

Firstly, Law 12,651/2012 allows that a Brazilian "smallholder" which can have 440 hectares, include the area of LRA in the same area of PPA in the cases when more than 25% of the rural property is covered by PPA and in other situations (Article 16).

With the creation of "consolidated rural area" in Law 12,651/2012, other advantages have been institutionalized for who occupied legal forests land. Any portion of PPA with some construction, crop or stockbreeding implemented before June 2008 can be pronounced a consolidated rural area by the owner, in the *Cadastro Ambiental Rural* (Rural Environmental Registry – CAR). Chart 2 presents the possibilities of PPA reduction in consolidated rural areas, according to the size of rural establishment or property.

Chart 2: Width of the Marginal Watercourse Range of the PPA with Consolidated Rural Areas

Establishment or Property Size (fiscal module)	Minimum Marginal Band (meters)
Less than 1	5
1 to 2	8
2 to 4	15
4 to 10	20
Higher than 10	30

Source: Law 12,651/2012, Article 61-A.

Moreover, the exigence of PPA around springs in consolidated rural areas has been reduced by 50 meters to 15 meters, beyond other facilities allowed in these situations[14].

Section 4 discusses the main legislation which allow agroforestry management in PPA and LRA and the limits of those uses in protected areas.

[14] Candiotto and Vargas (2018) provide additional information about Law 12,651/2012.

4 Agroforestry in Protected Areas

Despite PPA and LRA have been generally considered untouchable lands by many landowners, it is possible to use them in a conservation manner. Considering the importance of regulating these areas and restoring lands in properties that have environmental liabilities, it is necessary to advance the debate on forest management and other forms of conservationist use especially regarding agroforestry. Since 2006, Brazil institutionalized legislative tools which allow agroforestry systems in PPA and LRA.

4.1 Brazilian Normality Linked to Agroforestry in PPA and LRA

Through a review of the provisions of Law 11,428/2006, Law 12,651/2012, Decree 6,660/2008, Resolutions 369/2006, 425/2010 and 429/2011 of CONAMA and Normative Instruction (NI) 05/2009 of the Ministry of the Environment, we sought to analyze in what sense agroforestry systems can be implemented in LRA and PPA.

With Law 12,651/2012, some exigences of the other cited legislation have been changed or invalidated. But the presentation of some parts of these legislative tools show the possibilities to use agroforestry systems in PPA and LRA have been considered in Brazil.

Law 11,428/2006 established the use and protection of Atlantic Forest Biome. *Primary vegetation* (Art. 20) and *Secondary vegetation in an advanced stage of regeneration* (Art. 21) can only be suppressed for activities of public utility, scientific research, and preservationist practices with authorization. Nevertheless, cutting part of *Secondary vegetation in an advanced stage of regeneration* is authorized when necessary for small rural producers and traditional populations for the exercise of activities or agricultural, livestock or silvicultural activities essential to their subsistence and that of their family, except for PPA (Article 23).

In 2008, Decree 6,660 was launched, which identifies what can be done in the remnants of Native Atlantic Forest vegetation in terms of sustainable use. We highlight here the following aspects:

> - Possible exploration, with no direct or indirect commercial purpose, of native flora species originating from natural formations, for consumption on rural properties, possessions of traditional populations or small rural producers, with respect to primary vegetation and endangered species is free (Cap. II);
> - Ecological enrichment with native species is encouraged to restore biodiversity in the remaining secondary vegetation (Cap. III);

> - Planting and reforestation with native species can be done without the need for authorization from environmental agencies (it is also included, in a single paragraph in this provision of Art. 12, sustainable agroforestry management activities) (Cap. IV);
> - Cutting and exploitation of native species that are proven to be planted is permitted, provided they are registered and have authorization from the environmental agency (Cap. III);
> - Free collection of leaves, fruits and seeds is allowed during the periods of collection and maturation, if there is no risk to the survival of individuals and species collected (Cap. IV).

Items listed above are just some regulations for the use of the Atlantic Forest, which may be directly related to agroforestry management, given the restrictions and permissions of use. On the use of agroforestry systems in PPA, CONAMA Resolutions 369/2006, 425/2010 and 429/2011 complemented and strengthened the points made in the Forest Code of 1965 (Law 4,771/65).

CONAMA Resolution 369/2006 allows the existence of:

> exceptional cases in which the competent environmental agency may authorize the intervention or removal of vegetation in PPA for the implementation of works, plans, activities or projects of public utility or social interest, […] and of low environmental impact (BRASIL, 2006b, Article 1st).

Since agroforestry is considered an activity of social interest for smallholders and has a low environmental impact, it can also occur in PPA of small family rural establishments, if there is authorization from the competent Environmental Agency. The implementation of agroforestry is permitted both in PPA and LRA of family farms if there is no degradation or damage to the ecological function of the area. Though, CONAMA Resolution 369/2006 does not describe specific procedures.

CONAMA Resolution 425/2010 also defines exceptional cases of social interest in which the competent Environmental Agency can regularize intervention in vegetation in PPA with agroforestry management being one of those cases. It is set out in Section III of Article 2nd that social interests include “the activities of sustainable agroforestry management, as long as they do not degrade the vegetation cover and do not undermine the environmental function of the area”.

In CONAMA Resolutions 369/2006 and 425/2010, there are possibilities for agroforestry management in PPA by campesinos when the chance of enhancing the use of these areas has become greater.

In 2009, the NI 05 was the first legislative tool that defined methodological procedures for the restoration of PPA and LRA. In Chapter VII of this NI, the use of agroforestry is instituted as inducers to restore PPA in the property or possession of the family farmer, the campesino entrepreneur or traditional peoples and communities.

Based on subparagraph "b", item II of Article 2nd of CONAMA Resolution 369/2006 (which provides that agroforestry management practiced on small family farms or rural tenure cannot deprive the native vegetation cover or obstruct its restoration besides not harming the ecological function of the area), Article 9th of NI 05/2009 presents the requirements and procedures for the implementation of agroforestry in PPA, being:

> I - soil tillage and erosion control when necessary;
> II- the restoration and maintenance of the native vegetation, permanently maintaining the soil cover;
> III - establishment of at least 500 (five hundred) individuals per hectare of at least 15 perennial species native to local phytophysiognomy;
> IV - limitation of the use of agrochemical inputs, giving priority to the use of green manure;
> V - restriction of the use of the area for grazing domestic animals, except as provided in art. 11 of CONAMA Resolution 369, of 2006[15]
> VI - in the use of agricultural species of annual crops, the maintenance of the environmental function of the APP must be guaranteed and the provisions of Art. 10 of this Normative Instruction;
> VII - intercropping of perennial, native or non-invasive alien species, intended for the production and collection of non-wood products, such as fibers, leaves, fruits or seeds; and
> VIII - maintenance of established, planted and/or germinated seedlings, by crowning, control of disturbance factors such as competing species, insects, fire, or others and fencing or isolation of the area, when necessary and technically justified.

In addition to these two Resolutions, in 2011, CONAMA created Resolution 429, which presents the methodology for restoring PPA through sustainable agroforestry management practiced on small family farms (Article 6th of Chapter IV). In this standard, authorization from the competent Environmental Agency for the agroforestry of PPA is not required; still, similar aspects of NI 05 of 2009 must be considered. Both NI 05/2009 and CONAMA Resolution 429/2011 provide for procedures and requirements for developing agroforestry activity in PPA in a similar way. In general, the possibility of

[15] CONAMA Resolution 369/2006, Article 11, deals with what it considers of intervention or suppression of vegetation, eventual and of low environmental impact, in a PPA. Thus, in NI 05/2009 and in CONAMA Resolution 429/2011, the use restriction is for obtaining water by domestic animals, which is considered of low impact.

productive use is clear, limiting the activity mainly to non-wood products. These two standards also restrict the use of alien species in these areas, but while the NI 05/2009 obligated a minimum of native species composition (15 per hectare), CONAMA Resolution 429/2011 excluded this requirement. In whatever manner, with Law 12,651 published in 2012, alien species have been approved to be planted in consortium with regional native species through agroforestry systems.

4.2 Agroforestry Systems in PPA and LRA According to Law 12,651/2012

The Forest Code (Law 12,651/2012) is an important instrument that outlines how PPA and LRA should be applied to avoid degradation of remnant forests and permit forest regeneration of degraded areas. It provides possibilities for utilizing agroforestry systems in these areas especially in smallholder. This represents an advance in the sense that campesinos may be conducting agroforestry activity and at the same time, complying with the legislation (Dubois, 2008).

Agroforestry systems, mainly complex and agroecological, have been indicated and boosted in smallholders by Law 12,651/2012, in the context of "Social Interest" (Article 3rd, Section IX).

> The sustainable agroforestry exploitation practiced in the small family property or rural possession or by traditional peoples and communities, as long as it does not degrade the existing vegetation cover and does not undermine the environmental function of the area (Brazil, 2012, Article 3rd, Section IX, Line B).

Depending on the type of agroforestry management developed, agroforestry has the function of protecting the area, not degrading the forest cover, thus making it an acceptable and viable activity. In this sense, agroecological agroforestry are widely recommended for smallholders.

Another important instrument given by Law 12,651/2012 is the concept of Eventual Activities or of Low Environmental Impact, in which agroforestry activity is also included. Among the low-impact activities that may be related to diversified agroforestry systems, the following stand out:

> h) collection of non-wood products for subsistence purposes and production of seedlings, such as seeds, nuts and fruits, in compliance with specific legislation on access to genetic resources;
> i) planting of native species that produce fruits, seeds, nuts and other plant products, provided that it does not imply the suppression of existing vegetation or impair the environmental function of the area;

> j) agroforestry exploitation and sustainable, community and family forest management, including the extraction of non-timber forest products, if they do not disfigure the existing native vegetation cover or harm the environmental function of the area; (Brazil, 2012, Article 3rd, Section X).

Hence, extractive activities (collection of forest products, such as seeds, nuts, and fruits), the planting of native species, agroforestry and sustainable forest management are permitted in areas of LRA that are classified as small properties or family rural tenure, i.e., which have less than 4 fiscal modules. Nevertheless, if the LRA area is in a "consolidated rural area", it is stated that the LRA can be restored through the interspersed planting of native and exotic or fruit-bearing species, in an agroforestry system provided that the area recomposed with exotic species does not exceed 50% of the total area to be recovered (Article 66, Paragraph 3rd).

Chapter XII, Article 54 provides that:

> to comply with the maintenance of the legal reserve area in the properties referred in item V[16] of Art. 3, fruit tree plantations, either ornamental or industrial composed of alien species cultivated in interim system or in consortium with species native to the region in agroforestry systems (Brazil, 2012, Article 54).

In this case, the restoration of LRA with native species should be prioritized, so as not to degrade the natural biodiversity of each ecosystem. Knowing that it is necessary to expand technical assistance on agroforestry management for farmers, Sole paragraph of Article 54 set governmental institutions to provide technical support. In this matter, the governmental role for the expansion of diversified and agroecological agroforestry systems is fundamental.

In the same way, if rural tenure is classified as owned by a family farmer or rural family entrepreneur and part of the PPA is in a consolidated rural area[17], the owner will be able to recompose up to 50% of the degraded PPA with alien species. As the main function of PPA is to optimize the gene flow of animals and plants, we believe that the

[16] Item V of Article 3rd of Law No. 12,651/2012 defines small family property or rural tenure according to Article 3rd of Law 11,326/2006.

[17] To be considered a consolidated rural area, a given area must have been occupied until 22th July of 2008 and pronounced in the *Cadastro Ambiental Rural* (Rural Environmental Registry – CAR). However, as the CAR is still in the implementation phase and as the Environmental Regularization Program (ERP), instituted in Article 59 of Law 12,651/2012, has not yet been implemented, thus agroforestry use in PPA depends on the interpretation of environmental agencies state. Despite the delay in complying with the legislation and implementing its legal mechanisms, the most important thing here is to emphasize that there is the possibility of expanding the areas of agroforestry, both in LRA and in PPA that are to be restored.

authorization to plant alien species in these areas implies an unnecessary risk as it can generate competition between native and exotic species as well as invasion of the latter in areas that are ecologically important.

Article 41 says that the Federal Executive Government may institute programs to support and encourage environmental conservation, such as payment for environmental services or compensation for environmental conservation measures. Among the forms of compensation there should be lines of financing for sustainable forestry and agroforestry management. In Article 58, possibilities of governmental incentives for the handling of agroforestry and agrosilvopastoral systems are also mentioned.

5 Impressions About the Feasibility and Difficulties for Implementing Agroforestry in PPA and LRA

In spite of, the possibilities of agroforestry in PPA and LRA that are important protected areas in Brazil, there are situations where agroforestry land use may be a problem and not a solution. Ecologically, an agroforestry composition based on alien species can reduce biodiversity, mostly in cases where some alien (invasive) species surpress or outcompete native species.

While in LRA areas some exotic individuals could be used to generate biomass for the agroforestry system or supply the family's demand for firewood and wood, we understand that PPA should be managed primarily only with native species as they are important corridors of biodiversity.

Considering the flexibility of forestry legislation in Brazil is linked to the predominance of interests of landowners with large extension of land, it is necessary to be cautious when interpreting the legal provisions that allow the use of protected areas.

We believe that agroecological agroforestry systems fully recommended in degraded and protected areas as simple systems are not suitable for PPA and LRA. According to Santos, Crouzeilles and Sansevero (2019: 140), “[…] biodiverse agroforestry system is the best option to enhance biodiversity and ecosystem services (ES) in degraded areas where production systems based on sustainable management of natural resources are allowed by law”. Likewise, it is necessary to analyse the experiences of management and commission of agroforestry in PPA and LRA, to verify the practices that have been carried out and their ecological, social, and economic results.

Analysing Brazilian reality, Ewert et al. (2016: 103) alert that "the absence or inadequacy of protocols and registration systems stipulated in legal instruments, but incipiently established by environmental agencies has made the regulation of agroforestry practices practically impracticable."

Martins and Raniere (2014) have identified some limits of agroforestry use in Brazilian LRA. They argue that agroforestry systems in LRA areas need to be implemented "[…] on solid ecological bases, on the principles of ecological succession and on agroecological management practices." (p. 86). Considering that many kinds of agroforestry systems in Brazil have been established with limited species diversity (simple systems with alien species), the goals of environmental restoration and sustainable use of LRA need to be carefully analysed. In addition, there are problems with the institutional structure of Environmental Agencies for the management of native vegetation.

> The literature points out that the potential of simple agroforestry systems for conservation is quite limited and not guaranteeing the fulfilment of the LRA functions, especially regarding the protection of biodiversity. To achieve this objective, careful observation of the composition of the agroforestry system is recommended, especially regarding the richness and abundance of native species and their population dynamics over time. (Martins and Raniere, 2014: 88).

According to Deitenbach (2008) with the possibility of using agroforestry in PPA, farmers can adapt to the Legislation and take advantage of the resources available in these areas. However, there are some reservations regarding use.

> The important thing is that the agroforestry system to be installed must guarantee the protection function of the PPA in question. […] Therefore, it will not be any agroforestry system that can be authorized in PPA. […] Environmental authorities have little experience with this type of licensing, and it is therefore up to family farming organizations to make proposals for agroforestry systems (Deitenbach, 2008: 131).

Silva and Steenbock (2011) indicate that different productive practices or production and reproduction systems of distinct social groups do not correspond in laws, decrees or other legal instruments in the environmental area. This may erroneously assume that such practices are illegal and are often prohibited by the environmental agencies themselves. If agroforestry encounters barriers and/or difficulties to be regulated this is mainly due to the lack of knowledge about them.

Considering that diversified and agroecological agroforestry systems provides an ecologically balanced environment for present and future generations and restores ecological processes, they need to have protection and recognition from the government. In whatever way, to have legal support according to the provisions of Forest Code and other mentioned legislative tools, the question of the type of agroforestry needs to be raised as not all of them can be used.

Agroforestry plays an important role in the regeneration of vegetation, as well as in effecting the process of conservation and expansion of forest remnants. The use of this alternative in PPA and LRA is potentially favorable and is a strategy to regularize rural establishments.

The actual scenario of deforestation and environmental public policies regression in Brazil, in the context of Bolsonaro´s government, started in 2019 have been harming preservation and conservation possibilities. Regardless of the legal possibilities discussed in this paper, the Environmental Regularization Program (ERP) provided in Law 12,651 of 2012, as well as agroforestry management practices within the scope of the agroecological perspective, have not been advancing in Brazil. Thus, it is necessary to consider the weakness of Brazilian environmental agencies (Deitenbach, 2008; Martins and Raniere, 2014; Ewert et al., 2016).

Regarding legal means presented here, that could disseminate and support the use of agroforestry, Deitenbach (2008) comments that the Federal Government should consider the social interest, in most of cases, providing financing for family farmers, in addition to the environmental interest in the use of natural resources. Although the law provides for technical support for agroforestry management, it is necessary to move forward in this direction, prioritizing campesino smallholders.

More work is needed on the qualitative improvement and quantitative expansion of agroforestry systems in Brazil especially in smallholders. Therefore, it is necessary to advance public policies, funding, training of technicians and campesinos and other aspects, considering the importance of agroforestry in food security (Neves, 2013) and food sovereignty; to reduce the effects of climate change (Schembergue et al., 2017), expand carbon storage (Torres et al., 2014); and the advance of agroecology practices (Candiotto, 2020; Gregio, 2020).

According to Meirelles (2003), despite the offer of credit for the implementation of agroforestry, technical assistance has neither prioritized nor promoted strategies. Even NGOs working with agroforestry have not been able to expand them.

> With such problems remaining, the tendency is to maintain insecurity as farmers reject the introduction of trees on their properties. The damage falls on the entire society due to the difficulty of advancing feasible proposals that reconcile conservation and environmental restoration and production of food, wood, fibers, fuels, medicinal plants, and of environmental services (Méier et al., 2011: 14).

Méier et al. (2011: 14) states that, "when the management of agroforestry in PPA is configured, the posture of environmental agencies has been punitive and restrictive when it should be more instructive and informative". This punitive bias can result in farmers' rejection of implementing this form of land use.

According to Russo (2002: 77), agroforestry systems "should not be presented as a magic solution that will solve all environmental and social problems", but be promoted as a "correction of conduct in relation to PPA and LRA".

Certainly, agroforestry should not be seen as the only "solution" in discussions about the restoration of environments, but as a viable and promising mechanism. Depending on the ecological relevance of the area, as the case of PPA, the forest must be regenerated with only native species. Nonetheless, agroforestry can contribute to overcoming the idea that PPA and LRA are unproductive and unnecessary areas.

In addition, to being important alternatives for forest regeneration, the accomplishment of agroforestry systems in PPA and LRA allows to reconcile the restoration of degraded areas with the diversified production of food and other products, and may contribute to the expansion of agroecology, food sovereignty, improvement of smallholder livelihoods (Dawson et al., 2014) and the income of rural family.

In this manner, only to illustrate some examples of diversified agroforestry systems in Brazilian smallholders, it is interesting to mention experiences in different ecosystems.

1) The work of C*ooperafloresta*, located in Ribeira River Valley, in the east frontier between São Paulo State (Southeastern Region) and Paraná State (Southern Region). This experience has been analyzed in a book with 15 chapters organized by Steenbock et al. (2013), and in Ewert et al. (2016) paper;

2) The Ernst Götsch Syntropic Agriculture, created in Olhos D'Água Farm, in the South of Bahia State (Northeastern Region). It was analyzed in Götsch (1997); Gregio (2018; 2020) and on the website "agendagotsch.com";

3) Agroforestry systems in the Tomé-Açu municipality, Pará State (Northern Region / Amazon Region), which involve commercial farmers through Tomé-Açu Mixed Agricultural Cooperative (CAMTA) and campesinos linked to Association of Rural Family Farmers of the Municipality of Tomé-Açu (APPRAFAMTA). Pompeu, Kato and Almeida (2017) and Yamada (2009) analyzed elements of this experiences.

6 Conclusions

Agroforestry corresponds to new possibilities for ecological management, characterized by integrated cultivation, (whether of annual, perennial, forest, wood, ornamental, medicinal, native and/or alien plant species). They can restore deforested and degraded environments and conserve ecosystems and their biodiversity.

Important role in the restoration of native vegetation can be played by Agroforestry, as well as in effecting the process of conservation and expansion of forest remnants (Lundgren, 1982; Russo, 2002; Mead, 2004; Deitenbach, 2008; Paludo and Costabeber, 2012; Gregio, 2018). In this situation, some kinds of agroforestry have the potential to restore degraded lands, to improve conservation practices and to contribute to forest preservation (Santos, Crouzeilles and Sansevero, 2019). The use of this alternative in PPA and LRA is potentially favorable, being a viable and promising strategy to regulate rural context, mainly smallholders (Roshetko et al., 2008; Dawson et al., 2013; Dawson et al., 2014), which are mainly managed by campesinos.

Charging, punishing and demanding compliance from farmers and campesinos is not enough, it is necessary to create conditions that enable farmers to produce quality food, conserve natural resources, and restore the existent environment on their rural land (water, soil, forests).

Depending on the ecological relevance of the area, the most important aspect of PPA is to regenerate the forest with only native species. But exotic and alien species can be planted in LRA, either to serve as support for native species in the initial stages of implantation or to be used as products to support farm livelihoods or organic matter to cover and regenerate the soil.

718 Considering Law 12,651 of 2012, there are several opportunities to use
719 agroforestry systems in the process of forest restoration and legal regularization of
720 smallholders and in greater rural establishment. For example: 1) agroforestry systems can
721 improve to mitigate emissions of greenhouse gases (GHGs) through capturing and storing
722 atmospheric carbon (Torres et al., 2014); 2) campesinos and farmers can be benefited by
723 Payment for Environmental Services (PES); 3) agroforestry can optimize the creation of
724 ecological corridors, linking forest remnants, which are generally located in PPA and
725 LRA; 4) farmers that administer and have profit with agroforestry systems can expand
726 this kind of land usage beyond PPA and LRA; 5) agroforestry can contribute for river
727 basin planning and management, at various spatial scales, optimizing environmental and
728 territorial management.

729 Finally, this paper shows that Brazil has a forest legislation that allows combining
730 preservation, restoration and productive use, through agroecological and diversified
731 agroforestry systems. It can be used as an example in other countries and compared with
732 other initiatives and experiences around the world.

733 In the Brazilian context, the article highlights the importance of prioritizing
734 agroecological and diversified agroforestry systems (with native species and diverse
735 biodiversity) in LRA and PPA restoration, mainly in campesinos smallholders, to
736 contribute to environmental and social sustainability. If simple agroforestry systems (with
737 the introduction of alien species and a few diversity) expand in LRA and PPA, it can
738 hasten the problem of native biodiversity loss. So, simple agroforestry systems should be
739 used in degraded lands or to substitute other agriculture or pastureland use, but not in PPA
740 and LRA. Thus, institutions linked to environmental conservation and to campesinos need
741 to focus on agroecological and diversified agroforestry systems to reconcile food
742 production and forest restoration.

743 Agroforestry can contribute to expand sustainable land use strategies, along with
744 overcoming the idea that PPA and LRA are unproductive and unnecessary areas.
745 Nevertheless, for this alternative be actualized, there are many challenges, which may
746 require the proper application of forest legislation; the training of technicians and farmers
747 regarding the institution and management of agroforestry systems; the strengthening of
748 research and rural extension actions based on a conservation and integrated perspectives
749 between society and nature; the creation and implementation of public policies that
provide subsidies, credits or funds for the expansion of agroecological agroforestry
systems in Brazil.

HIGHLIGHTS

Forests preservation and restoration are crucial to sustain ecological and social benefits.

In the context of forest restoration, agroforestry systems are important land use instrument because they allow sustainable forest management combined with food production.

Brazil's forest legislation permits to combine preservation, restoration, and productive uses in Legal Reservation Areas (LRA) and Permanent Preservation Areas (PPA), which are protected lands of rural properties.

This paper discusses possibilities and limitations to introduce agroforestry systems in Brazil through LRA and PPA, highlighting the importance of agroecological and diversified agroforestry systems.

Agroforestry systems are also viable for the restoration of degraded areas and for expanding forested areas and uses of their natural resources, especially in campesino properties.

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