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AGROFORESTRY AS A TOOL FOR RESTORATION IN ATLANTIC FOREST: CAN WE FIND MULTI-PURPOSE SPECIES?

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ABSTRACT
Agroforestry Systems (AFS), especially multistrata or multilayer AFS, are a feasible tool for forest restoration. The presence of native species in AFS enables forest regeneration whereas brings back forest structure and also recovers some functions and environmental services. At the same time, they can produce a range of annual and perennial crops and trees that provide food and income over time. In this way, it is crucial the selection of species which compose AFS in order to play in the best ecological and economic roles considering local conditions. Our goal was to find multi-purpose species that could supply forest products, and could be used in restoration and agroforestry initiatives in Brazilian Atlantic Forest, by analyzing secondary data. We identified 92 potential tree species as raw material for forest management belonging to 11 categories of timber and non-timber products and identified their functional attributes in AFS. Most of these species allows non-timber products management, ensuring the long-term permanence of forest structure, which is more compatible with restoration processes.
Keywords: agroforestry systems; Atlantic Forest; native tree species.

INTRODUCTION

Since the 16th century the Brazilian Atlantic Forest (BAF) has been degraded by the intensive use of natural resources (Dean 1996). Gradually, its ecosystems have been fragmented and replaced by urban and agricultural areas (Rodrigues *et al.* 2011) and also by monocultures covering large areas. According to Ribeiro *et al.* (2009), less than 12% of the original vegetation cover is left in the biome.

Deforestation and forest landscapes degradation are processes that demand attention in most tropical countries. Historically, these processes have caused the vanishing of forest physiognomies, extinction of species, fragmentation of ecosystems, and the loss of many goods and services, leading to the development of ecological restoration techniques as a solution. These techniques/actions can focus on different ecosystem types in different scales, from degraded sites to entire landscapes (Hobbs &Norton 1996, Ehrenfeld 2000, Holl *et al.*2003, Lamb *et al.* 2005). Many authors discuss the use of different models to restore degraded lands: forest plantations, enrichment plantings, agroforestry, silvopastoral systems (Lundgren 1985, Duchhart *et al.* 1988, Prinsley 1992, Lamb *et al.* 2005, Garen*et al.*2009, Vieira *et al.* 2009, Suárez *et al.* 2012). All these systems deal with the use (or integration) of tree species in rural landscapes. Most deliberate efforts to overcome degradation involve tree planting: reforestation has been the main effort to overcome the degradation of tropical forests, and plantations of native-tree species are often recommended for forest restoration (Lamb *et al.* 2005, Montagnini*et al.* 2005, Hall *et al.* 2011, Sansevero *et al.* 2011, Le *et al.* 2012).

In an ecological view, restoration focuses on desired structural attributes, a minimum species composition and functional aspects, according to the ecosystem trajectory over time (Suganuma & Durigan 2014). But restoration of forest landscapes have ecological, cultural and socioeconomic dimensions and demands sustainable management alternatives that will allow forest conservation and restoration (Suárez *et al.* 2012). Successful forest restoration in rural areas requires the integration of ecology, agronomy, and traditional knowledge in a way that engages farmers and landowners in resource conservation (Chazdon

2008, Vieira *et al.* 2009). According to Lamb *et al.*(2005) neither agricultural development nor past forms of reforestation have been sufficient to provide sustainable livelihoods and environmental services over the large areas of degraded land. Taking this into account it is important to establish ecological restoration efforts focused on reestablishing high-diversity tropical forests and incorporating possibilities of exploiting forest products (Calmon *et al.* 2011) that allow an integration in the landscape with agricultural production (Carvalhaes *et al.* 2008, Oliveira *et al.* 2008).

According to SER - Society for Ecological Restoration (2004) "ecological restoration may accept and even encourage new culturally appropriate and sustainable practices that take into account contemporary conditions and constraints" and the evaluation of restoration "include the assessment of any stated goals and objectives that pertain to cultural, economic and other societal concerns".

We believe that Agroforestry Systems (Combe 1982, Somarriba 1992) are a possibility for forest restoration or at least for a best integration of forests (or tree species) all over the Brazilian Atlantic Forest rural landscape, since they can help bringing back part of forest ecosystems structure and biodiversity, and can also recover some functions and environmental services in these areas. Multistrata or multilayer AFS can create a vertically stratiûed forest by accelerating succession and forest regeneration in many areas, and thereby minimizing restoration costs by producing a range of annual and perennial crops and trees that provide food and income over time. Besides, many of the functions, aspects or advantages described to AFS can be considered consistent with restoration goals.

Agroforestry can describe or include productive and protective systems (Combe 1982) that can sustain profitable agricultural production and improve human nutrition (Styger*et al* 1999, Aronson *et al.* 2002), and can also contribute to maintain and recover a significant part of biodiversity, enhancing ecological processes (Ilany*et al.* 2010). Agroforestry Systems can be a promising choice to biological diversity restoration and conservation, including several species of trees (Styger*et al.* 1999, Aronson *et al.* 2002, Huang *et al.* 2002, Silva Moço 2009).They may be important tools to reduce edge effects between forests and agricultural land and to connect forest remnants, as biological corridors and stepping stones (Schroth*et al.* 2007, Chazdon 2008, Chazdon *et al.* 2009, Jose 2009, Lillesø *et al.* 2011).

There are distinct models and practices associated to traditional AFS used in the BAF, like forest fallow, shade cacao plantations, shade grown coffee, banana agroforestry plantations, agroforestry systems with "yerba mate", taungya systems, and others (May &Trovatto 2008), but only recently there have been experiences with the objective of using AFS as restoration actions (Engel & Parrotta 2000, Rodrigues *et al.* 2007, Daronco *et al.* 2012). Selecting appropriate species can be useful for formulating and implementing sustainable management alternatives that will allow forest restoration, and economic sustainability of AFS (Jose 2011, Suárez *et al.* 2012).

Some authors point out that generally, the use of native species is preferable because they are already adapted to the environment, are not a risk as invasive species, and are able to offer many ecological and economic advantages, as diversification and increase in farm income (Palmberg 1986, Prinsley 1992, Alavalapati *et al.* 2004, Piotto *et al.* 2004, Montagnini 2004, Kindt *et al.* 2006, Suárez *et al.* 2012). The use of native species is also preferable and more acceptable in restoration initiatives (Society for Ecological Restoration 2004) and, if a set of species can serve a number of different purposes and provide a range of goods and services, they will be more easily accepted by local people.

The use of native species in AFS is an important strategy to return trees and forests to the Brazilian agricultural landscape. There are hundreds of tree species in the different forest physiognomies all over BAF and, usually, a great diversity of species is required for restoration actions in this biome. Considering that the use of these species in AFS should be prioritized or recommended, the challenge lies on searching information about native tree species that join ecological and agricultural desirable functions. This article focuses on the proposal of potential multipurpose native tree species and their functions to be managed in AFS in different regions of the Brazilian Atlantic Forest, which could be used in projects, actions and researches focused on forest restoration, and make restoration an extra source of income.

MATERIAL AND METHODS

The preparation of our list of multi-purpose species was based on literature review and secondary data. A first survey was performed through access of websites (of institutes, non-governmental organizations, researchers, associations and commercial sites), papers, books and gray literature to find forest resources and products already commercialized, coming from BAF native species which had been used in restoration projects. In a second survey, we searched for information regarding which of these species had potential to be used in multilayer AFS.

A first list of species was built including only tree species, cited as "providers of forest products"and "suitable for management", usually used in forest restoration projects in BAF landscape. We did a complementary survey about their economic potential and searched for information regarding the species and their ecological aspects (architecture, pollination and seed dispersal syndromes, types of fruit, successional category, and which of them were legume trees). The possible functions of species in an AFS are: economical (flagship species); environmental services provider (shade, biological control, organic matter and nutrient supplier etc.); auxiliary roles (filling or temporary species); and biodiversity provider.

The desired functions (or functional attributes of these species in agroforestry systems) would be: biodiversity (species richness), attraction for wildlife, nutrient fixation and cycling (see Canosa *et al.* 2012), shade and sources of income. Based on literature review and on our personal field experience, the species were categorized according to their role (or function) within multilayer AFS. Species were chosen and listed according to their potential to be used in AFS:

1- Biodiversity*:* refers to the potential of the species in increasing biodiversity and providing sustainability (by increasing ecological stability) to both system and landscape (we considered that all species have this role in AFS);

2- Attraction for wildlife: refers to the catalyzing effect of those native species in attracting potential pollinators and seed dispersers (so called mobile links), and even other groups that are able to control pests and diseases;

3- Nutrient fixation and cycling: despite all selected species can potentially contribute for nutrient fixation and cycling, these criteria include only species that are usually used in restoration or agroforestry projects for this specific purpose;

4- Shade: shade species are those which grow fast and have favorable architectural traits to perform that function in an AFS;

5- Sources of income: potential yields and income species were attributed to those with a potential market or a known production chain and considering the products attributed to them in literature. The products surveyed by those species were divided into two categories: TFP (timber forest products) and NTFP (non-timber forest products), and distributed over 11 distinct classes that were based on potential uses suggested by the papers analyzed:

a) NTFP: ornamental plants (OR); handcraft (HA); medicinal, cosmetic or pharmaceutical (ME); food (FO); dyestuff (DY); fiber (FI); chemical products (CH), as oils, tannin, and resin; and honey plants (HO);

b) TFP: solids (S) – includes wood for beams, furniture, packing boxes, heavy construction etc.; energy supply (EN); handcraft (HA).

RESULTS

We found four papers containing information on products associated to BAF tree species (Carvalhaes *et al.* 2008, Oliveira *et al.* 2008, Preiskorn *et al.* 2009, Cardoso-Leite *et al.* 2010), and 172 species were initially listed. From that first list containing 172 tree species, according to the methods already described here, 92 species belonging to 32 plant families were selected as able to be used in AFS associated to forest restoration, concerning their role in these systems (Table 1); that is, those species were considered able to perform one or more of the desired functions (or functional attributes) and were identified as "multiple use trees", and as potential suppliers of the TFP and NTFP listed here.

Many species listed here (34) can supply more than a type of product, and all species listed (92) may match more than one function in AFS. None can match all the functions listed, but most of them (64%) may match at least three functions in AFS. Since these 92 species are native species, they were all considered to be important for providing, enhancing, and conserving biodiversity.

From the 92 species listed, 75 are forest products suppliers. The classification based on type of products provided suggests that 15 species are both TFP and NTFP suppliers, 33 are exclusively NTFP suppliers, and 27 supply exclusively TFP. The results found here indicate the potential of use and management of a diverse list of products: 46% of species can supply solid wood; 23% have potential for ornamental, 22% for food, and 17% were for medicinal products. Besides, 16 species (18%) can supply fiber, chemical products and dyestuff, can be used in handcrafting, and provide wood for energy purposes.

Table 1. Species surveyed, types of products supplied, and classification based on ecological groups and potential functions (or functional attributes) in agroforestry systems (TFP=timber forest products, NTFP=Non-timber forest products. Functions: 1=Biodiversity, 2=Attraction for wildlife, 3=Nutrient fixation and cycling, 4=Shade, 5=Sources of income. Classes of uses: ornamental plants (OR), handcraft (HA), medicinal, cosmetic or pharmaceutical (ME), food (FO), dyestuff (DY), fiber (FI), chemical products (CH), honey plants (HO), solids (S), energy supply (EN).

Species (Family)	Product		Classes of uses	Function
	TFP	NTFP		
Acrocomia aculeata (Jacq.) Lodd. ex Mart.(Arecaceae)		x	FO, CH	1, 2, 4, 5
Alchornea triplinervia (Spreng.) Müll. Arg. (Euphorbiaceae)				1, 2, 3, 4
Acajuba occidentalis (L.) Gaertn. (Anacardiaceae)		x	FO, OR	1, 2, 5
Anadenanthera colubrina (Vell.) Brenan (Fabaceae)	x	x	S, EN, CH	1, 3, 5
Anadenanthera macrocarpa (Benth.) Brenan (Fabaceae)	x	x	S, EN, CH	1, 3, 5
Annona cacans Warm. (Annonaceae)		x	FO	1, 2, 5
Araucaria angustifolia (Bertol.) Kuntze (Araucauriaceae)	x	x	S, FO	1, 2, 5
Aspidosperma cylindrocarpon Müll. Arg. (Apocynaceae)	x		S	1, 5
Macaglia olivacea (Müll. Arg.) Kuntze (Apocynaceae)	x		S	1, 5
Thyroma polyneura (Müll. Arg.) Miers (Apocynaceae)	x		S	1, 5
Macaglia subincana (Mart. ex A. DC.) Kuntze (Apocynaceae)	x	x	S, ME	1, 3
Astronium graveolens Jacq. (Anacardiaceae)	x		S	1, 5
Attalea funifera Mart. (Arecaceae)		x	FI	1, 5
Bactris setosa Mart. (Arecaceae)		x	OR, HA	1, 2, 5
Balfourodendron riedelianum (Engl.) Engl. (Rutaceae)	x		S	1, 3, 5
Bauhinia forficata Link (Fabaceae)		x	ME	1, 2, 3, 5
Orellana orellana (L.) Kuntze (Bixaceae)		x	OR, DY, FO	1, 2, 5
Cebipira virgiliodes (Kunth) Kuntze (Fabaceae)		x	ME, CH	1, 3, 5
Cabralea canjerana (Vell.) Mart. (Meliaceae)	x		S	1, 3, 4, 5
Guilandina echinata (Lam.) Spreng. (Fabaceae)	x	x	S, DY	1, 3, 5
Calophyllum brasiliense Cambess. (Calophyllaceae)	x		S	1, 5
Paivae aphaea (O. Berg) Mattos (Myrtaceae)		x	FO	1, 2, 5
Britoa guazumifolia (Cambess.) D. Legrand (Myrtaceae)		x	FO, OR	1, 2, 5
Cariniana estrellensis (Raddi) Kuntze (Lecythidaceae)	x		S	1, 4, 5
Cariniana legalis (Mart.) Kuntze (Lecythidaceae)	x		S	1, 4, 5
Guidonia sylvestris (Sw.) Maza (Salicaceae)		x	ME	1, 2, 4, 5
Cecropia glaziovii Snethl.		x	OR, ME	1, 2, 3, 4
Ambaiba pachystachya (Trécul) Kuntze (Urticaceae)		x	OR, ME	1, 2, 3, 4
Centrolobium tomentosum Guillemin ex Benth. (Fabaceae)	x		S	1, 3, 4

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Species (Family)	Product		Classes of uses	Function
	TFP	NTFP		
Copaiba langsdorffii (Desf.) Kuntze (Fabaceae)	x	x	ME, S	1, 2, 5
Gerascanthus trichotomus (Vell.) M. Kuhlm. & Mattos (Boraginaceae)	x		S	1, 3, 5
Croton floribundus Lund ex Didr. (Euphorbiaceae)			-	1, 2, 3, 4
Oxydectes urucurana (Baill.) Kuntze (Euphorbiaceae)			-	1, 2, 3, 4
*Citharexylum myrianthum*Cham. (Verbenaceae)			-	1, 2, 3, 4
Schefflera morototoni (Aubl.) Maguire, Steyerm. & Frodin (Araliaceae)			-	1, 4
Enterolobium contortisiliquum (Vell.) Morong (Fabaceae)	x		S	1, 3, 4
Corallodendron falcatum (Benth.) Kuntze (Fabaceae)		x	OR	1, 2, 3, 4
*Erythrina specios a*Andrews (Fabaceae)		x	OR	1, 2, 3, 4
Eschweilera ovata (Cambess.) Miers (Lecythidaceae)	x		S	1, 5
*Esenbeckia leiocarpa*Engl. (Rutaceae)	x		S	1, 2, 5
Pseudomyr cianthespyriformis (Cambess.) Kausel (Myrtaceae)		x	FO	1, 2, 5
Stenocalyx uniflorus (L.) Kausel		x	OR, FO	1, 2, 5
*Euterpe edulis*Mart. (Arecaceae)		x	OR, HA, FO	1, 2, 5
Gallesia integrifolia (Spreng.) Harms (Phytolaccaceae)	x		S	1, 3, 4, 5
Genipa americana L. (Rubiaceae)		x	OR, FO	1, 2, 3, 4, 5
Moquiniastrum polymorphum (Less.) G. Sancho (Asteraceae)	x	x	S, ME, CH,	1, 3, 5
Guazuma guazuma var. *ulmifolia* (Lam.) Kuntze (Guazuma)		x	ME	1, 2, 3, 4
Holocalyx balansae Micheli (Fabaceae)	x		S	1, 3, 4, 5
Courbaril hymenaea G. M. (Fabaceae)	x	x	S, ME, CH, HA, FO	1, 2, 3, 4, 5
Ilex paraguariensis A. St.-Hil. (Aquifoliaceae)		x	ME, FO	1, 5
Feuilleea edulis (Mart.) Kuntze (Fabaceae)		x	OR, HO	1, 2, 3, 4
Feuilleea laurina (Sw.) Kuntze (Fabaceae)		x	OR, HO	1, 2, 3, 4
*Inga uruguensis*Hook. & Arn. (Fabaceae)		x	OR, HO	1, 2, 3, 4
Jacaranda micranta Cham. (Bignoniaceae)	x		S	1, 3, 4, 5
Jacaratia spinosa (Aubl.) A. DC. (Caricaceae)		x	ME, FO	1, 2, 4, 5
Dahlstedtia muehlbergiana (Hassl.) M.J. Silva & A.M.G. Azevedo (Fabaceae)			-	1, 2, 3, 4
Luehea divaricata Mart. (Malvaceae)		x	HO	1, 3, 4
Machaerium stipitatum (DC.) Vogel (Fabaceae)			-	1, 3, 4
Machaerium villosum Vogel (Fabaceae)			-	1, 3, 4
Maytenus officinalis Mabb.(Celastraceae)		x	ME	1, 2, 5
Mimosa scabrella Benth. (Fabaceae) Ok’s	x	x	S, HO, EN	1, 2 3, 5
Astronium urundeuva (Allemão) Engl. (Anacardiaceae)	x		S	1, 3, 5
Plinia trunciflora (O. Berg) Kausel (Myrtaceae)	x		FO	1, 2, 5
Myrocarpus frondosus Allemão (Fabaceae)	x	x	S, CH	1
Oxydectes urucurana (Baill.) Kuntze (Euphorbiaceae)			-	1, 2, 3, 4
Citharexylum myrianthum Cham. (Verbenaceae)			-	1, 2, 3, 4
Schefflera morototoni (Aubl.) Maguire, Steyerm. & Frodin (Araliaceae)			-	1, 4
Enterolobium contortisiliquum (Vell.) Morong(Fabaceae)	x		S	1, 3, 4
Corallodendron falcatum (Benth.) Kuntze (Fabaceae)		x	OR	1, 2, 3, 4

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Species (Family)	Product		Classes of uses	Function
	TFP	NTFP		
Erythrina speciosa Andrews (Fabaceae)		x	OR	1, 2, 3, 4
Eschweilera ovata (Cambess.) Miers (Lecythidaceae)	x		S	1, 5
Esenbeckia leiocarpa Engl. (Rutaceae)	x		S	1, 2, 5
Pseudomyr cianthespyriformis (Cambess.) Kausel (Myrtaceae)		x	FO	1, 2, 5
Stenocalyx uniflorus (L.) Kausel		x	OR, FO	1, 2, 5
*Euterpe edulis*Mart. (Arecaceae)		x	OR, HA, FO	1, 2, 5
Gallesia integrifolia (Spreng.) Harms (Phytolaccaceae)	x		S	1, 3, 4, 5
Genipa americana L. (Rubiaceae)		x	OR, FO	1, 2, 3, 4, 5
Moquiniastrum polymorphum (Less.) G. Sancho (Asteraceae)	x	x	S, ME, CH,	1, 3, 5
Guazuma guazuma var. *ulmifolia* (Lam.) Kuntze (Guazuma)		x	ME	1, 2, 3, 4
Holocalyx balansae Micheli (Fabaceae)	x		S	1, 3, 4, 5
Courbaril hymenaea G. M.(Fabaceae)	x	x	S, ME, CH, HA, FO	1, 2, 3, 4, 5
Ilex paraguariensis A. St.-Hil.(Aquifoliaceae)		x	ME, FO	1, 5
Feuilleea edulis (Mart.) Kuntze (Fabaceae)		x	OR, HO	1, 2, 3, 4
Feuilleea laurina (Sw.) Kuntze (Fabaceae)		x	OR, HO	1, 2, 3, 4
*Inga uruguensis*Hook. & Arn. (Fabaceae)		x	OR, HO	1, 2, 3, 4
Jacaranda micranta Cham. (Bignoniaceae)	x		S	1, 3, 4, 5
Jacaratia spinosa (Aubl.) A. DC.(Caricaceae)		x	ME, FO	1, 2, 4, 5
Dahlstedtia muehlbergiana (Hassl.) M.J. Silva & A.M.G. Azevedo (Fabaceae)			-	1, 2, 3, 4
Luehea divaricata Mart. (Malvaceae)		x	HO	1, 3, 4
Machaerium stipitatum (DC.) Vogel (Fabaceae)			-	1, 3, 4
Machaerium villosum Vogel (Fabaceae)			-	1, 3, 4
Maytenus officinalis Mabb.(Celastraceae)		x	ME	1, 2, 5
Mimosa scabrella Benth. (Fabaceae) Ok's	x	x	S, HO, EN	1, 2 3, 5
Astronium urundeuva (Allemão) Engl. (Anacardiaceae)	x		S	1, 3, 5
Plinia trunciflora (O. Berg) Kausel (Myrtaceae)	x		FO	1, 2, 5
Myrocarpus frondosus Allemão (Fabaceae)	x	x	S, CH	1
Nectandra megapotamica (Spreng.) Mez (Lauraceae)	x	x	S, OR	1, 2
Ocotea catharinensis Mez (Lauraceae)	x		S	1, 2
Ocotea odorífera Rohwer (Lauraceae)	x		S	1, 2
Cinnamo mumporosum (Nees & Mart.) Kosterm. (Lauraceae)	x		S	1, 2
Ocotea pretiosa (Ness & Mart.) Mez (Lauraceae) Ok's	x		S	1, 2
Ocotea velloziana (Meisn.) Mez (Lauraceae)	x		S	1, 2
Parapiptadenia rigida (Benth.) Brenan (Fabaceae)	x	x	S, EN	1, 3, 5
Baryxylum dubium (Spreng.) Pierre (Fabaceae)	x		S	1, 3, 4
Pityrocarpa gonoacantha (Mart.) Brenan			-	1, 3, 4
Tingulonga heptaphylla (Aubl.) Kuntze (Burseraceae)		x	ME	1, 2, 5
Pseudobombax grandiflorum (Cav.) A. Robyns (Malvaceae)		x	OR	1, 3, 4
Psidium araca Raddi (Myrtaceae)		x	FO, OR	1, 2
Psidium cattleyanum Sabine (Myrtaceae)		x	FO, OR	1, 2
Myrsine guianensis (Aubl.) Kuntze (Primulaceae)			-	1
Garcinia gardneriana (Planch. &Triana) Zappi (Clusiaceae)		x	FO	1, 2

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Species (Family)	Product		Classes of uses	Function
	TFP	NTFP		
*Schinus molle*L. (Anacardiaceae)			-	4
Schinus terebinthifolius Raddi (Anacardiaceae)	x	x	S, EN, FO, ME	1, 2, 3, 4, 5
Schizolobium parahyba (Vell.) S.F. Blake (Fabaceae)	x		S	1, 3, 4
Senna multijuga (Rich.) H.S. Irwin & Barneby(Fabaceae)			-	1, 4
Spondias mombin L. (Anacardiaceae)		x	FO	1,2,5
Syagrus romanzoffiana (Cham.) Glassman (Arecaceae)			-	1, 2
Handroanthus avellanedae (Lorentz ex Griseb.) Mattos (Bignoniaceae)	x	x	S, OR, ME	1, 5
Handroanthusheptaphyllus (Vell.) Mattos (Bignoniaceae)	x	x	S, OR	1, 5
Handroanthus impetiginosus (Mart. ex DC.) Mattos (Bignoniaceae)	x	x	S, OR	1, 5
Magnolia ovata (A. St.-Hil.) Spreng. (Magnoliaceae)			-	1, 2, 4
Trema micranta(L.) Blume (Cannabaceae)			-	1, 2, 3, 4
Fagara riedeliana (Engl.) Engl (Rutaceae)			-	1, 3, 4
Zeyheria tuberculosa (Vell.) Bureau (Bignoniaceae)	x		S	1, 4

DISCUSSION

Trees are generally multi-purpose (Palmberg 1986), combined productive and protective functions, and have a range of uses. If proper species can be selected for restoration, they will offer both ecological and economic advantages (Combe 1982). The species listed here are already used in forest restoration projects, and are supposed to bring structure (as tree species), to improve species composition (as native trees) and to ensure – at least partially – some functions, such as attracting pollinators and seed dispersers, contribute to nutrient cycling, and others.

Some authors refer to the economic potential of forest restoration plantations or job generation and income opportunities through the restoration supply chain (Calmon *et al.* 2011). Nevertheless, we found only four papers containing information on Atlantic Forest tree species and their associated products. On the other hand, more than half (54%) of the species are potential sources of income, which means they have economic potential.

The species listed are timber and non-timber products suppliers and are likely to be used in restoration actions. AFS have some characteristics which can be considered as desired goals for restoration, as pointed out by Jose *et al.* (2012): (i) high structural and floristic diversity (*e.g.* multiple species and vegetative strata); (ii) minimal management intensity; (iii) long rotation periods; and (iv) strategic locations on the landscape (*e.g.* close to large natural habitats or within it. The so called multi-purpose trees are those which provide many ecological functions, uses, products, and services. These species are favored in AFS for providing many products and improving sustainability, since trees tend to be long-lived (Nair *et al.* 1984, Nair 1987, Thaman *et al.* 2000).

The economic potential from the use and management of those species indicate which AFS can be recommended to forest restoration projects, since they may allow: (i) mid- and short-term cash flow, through the production of timber and non-timber products; (ii) the amortization of the excessively high costs of forest restoration, which do not allow people to restore forests in agricultural landscapes; and (iii) the access of small farmers to special markets and payment schemes for environmental services discussed in Brazil.

It is also important to discuss if those species and systems could be interesting or valued by landowners. We agree with Alavalapati *et al.*(2004) postulation, that if nonmarket goods and services can be internalized to the benefit of landowners, the adoption of AFS would increase. Different reasons motivate landowners to restore degraded portions of their farms. One of the key factors in determining agroforestry adoption is its relative profitability in comparison with other land-use practices. Thus, farmers will invest in agroforestry when the expected gains from the new system are higher than the alternatives for the use of their land (Mercer 2004, Rodrigues *et al.* 2011).

Agroforestry is not usually used in restoration projects in Brazil, but there have been some experiments with taungya systems (Engel &Parrotta 2000, Rodrigues *et al.* 2007, Daronco *et al.* 2012). The results from these experiments showed that intercropping trees and annual crops could be an important alternative for promoting forest restoration in small farms. Economic evaluations proved that AFS could be useful in the recovery of areas in rural properties, with associated income provided by crops production during the first years, and could help minimizing restoration costs. This may be a good reason for these systems to be adopted by farmers, as one of the key limitations to the use of restoration plantings is their high cost (Lamb *et al.* 2005, Oliveira *et al.* 2008, Cardoso-Leite *et al.* 2010).

Also, when associated with sustainable management activities, AFS are considered an option for legal compliance of rural properties. In Brazil, legal regulations have been discussed over the last twenty years, and changes have been gradually occurring, like specific laws referring to forest management, restoration, and conservation (Simmons *et al.* 2002, Calmon *et al.* 2011). The Federal law 12.651/2012 (Brasil 2012) states that any rural property must keep at least 20% of its area covered by natural vegetation, and this percentage must be restored if the original vegetation is removed or affected by anthropic influence. Restoration actions allowed include conduction of natural regeneration associated with forest plantations and forest models with native and exotic species. In these areas - called legal reserves - forest management is allowed and at least 50% of the trees planted are supposed to be native species. CONAMA (Environment National Council) Resolution 369/2006 consider agroforestry management an activity of social interest for small properties that are characterized with family farming, also in protected areas (Brasil 2006). These laws state the potential and economic importance of models associated with management on rural properties and characterize them as possible restoration strategies.

Landholders are interested in planting native trees with traditional uses, and prefer trees that provide multiple products (Garen *et al.* 2009, Souza *et al.* 2010). Local availability and market opportunities are determining factors for selecting those multiple use trees. In a study developed in Panama about the adoption of AFS, Fischer &Vasseur (2002) found that participants in most projects planted trees for timber products, and the most common benefits mentioned by farmers were that trees provide fruit, fuelwood (energy), and wood for domestic consumption. All these goals are provided by most species found in this study.

According to Simmons *et al.* (2002), species selection is essentially an economic decision, and so is the decision to incorporate trees into a farming system. These authors point out other factors beyond economic motivation and legislation that may contribute to tree planting, such as labor availability, access to credit, and marketing assistance. Suárez *et al.*(2012) searched for species for forestry restoration, AFS, and enrichment plantings that could be valued by landowners; these authors cite some characteristics, such as importance for wildlife, uses (different products providers), and rarity. These characteristics - besides rarity, not considered here - are found in the species we listed. Discussing species selection for restoration, these authors cite as interesting species those with successful propagation techniques and currently available in the nurseries of the region. All species listed in this study have seeds and seedlings already produced in nurseries in many regions of BAF.

In conclusion, AFS are currently used in the Atlantic Forest and in Brazil as a whole mostly by small landholders and family-based agriculture (May & Trovatto 2008). Existing experiences and technology should be better investigated, in order to be used in large scale. It is important to demonstrate agroforestry as a viable system in comparison to current agricultural models.

The biodiversity is still underexploited in restoration actions in BAF, despite the great potential in this biome. The possibility and viability of integrating native species to production systems suggest that there is a promising solution, and a participative research with actors and agents involved with sustainable rural development should be stimulated. The use of native tree species integrated to production systems represent a great advance by overlapping technology developed for food production and food sovereignty, for silviculture, for conservation of biodiversity, and for providing environmental services. The results discussed here clearly indicate the potential of many native tree species tobe used as multipurpose species in AFS, and shows the possibility of maintaining trees in agricultural landscapes. As a matter of fact, such potential may be underestimated in the present study because of the large species richness in that ecosystem. Our results considered only 92 species in forest restoration projects, which is a small part of a great amount of tree species with potential to be used in forest and agroforestry systems, It is also important to point out the potential of AFS for forest and landscape restoration, allowing the enhancement of connectivity, and the rescue of part of the biological diversity by planting tree species.

Finally, we truly believe that AFS containing these native tree species can be an interesting alternative for rural owners to legalize their situation, since landholders in Brazil are obligated by law to restore forests in deforested landscapes.

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