II WORLD CONGRESS ON INTEGRATED CROP-LIVESTOCK-FORESTRY SYSTEMS
May 4th and 5th, 2021 - 100% Digital

SELECTION OF SPECIES FOR IMPLANTATION IN LOW-CARBON TECHNOLOGY IN THE BRAZILIAN ATLANTIC FOREST

Julia Graziela da SILVEIRA [1]; Luís Tadeu ASSAD [2]; Sílvio Nolasco de Oliveira NETO [3]; María Suárez BONET [4]; Fernanda Figueiredo Granja Dorilêo LEITE [5]; Ana Carolina Barbosa do CANTO [6]; Fernanda Reis CORDEIRO [7]; Alejandro Muñoz MUÑOZ [8]; Marília Beatriz de Castro RAMOS [9]; Renato de Aragão Ribeiro RODRIGUES [10]

[1] Forest Engineer. PhD candidate. Department of Forest Engineering, Federal University of Viçosa (UFV); [2] Fisheries Engineer. Director-President. Brazilian Institute of Development and Sustainability (IABS); [3] Forest Engineer. Professor. Department of Forest Engineering, Federal University of Viçosa (UFV); [4] Industrial Engineer. Operational Coordinator. Brazilian Institute of Development and Sustainability (IABS); [5] Agricultural and Environmental Engineer. PhD candidate. Federal Fluminense University (UFF); [6] Agricultural and Environmental Engineer. Master in Biosystems. Federal Fluminense University (UFF); [7] Agricultural and Environmental Engineer. PhD candidate. Federal Fluminense University (UFF); [8] Degree in Marine Sciences. Director of Internationalization. Brazilian Institute of Development and Sustainability (IABS); [9] Forest Engineer. Field Coordinator. Brazilian Institute of Development and Sustainability (IABS); [10] Biologist. Researcher. Embrapa Soils

ABSTRACT
The Atlantic Forest has a history of agricultural occupation and expansion that changed the original ecosystem, increase loss of native vegetation and degraded areas. By adopting low-carbon technologies, producers can promote food security and contribute to mitigate climate change. This type of technology is practicable through projects such as Sustainable Rural. The success of this type of project is related to the appropriate choice of species for different environmental conditions. Thus, the objective of this work was to identify, from trained specialists and rural producers, the main species for implantation of different low-carbon technologies in the Atlantic Forest, being: Agroforestry Systems (AFS), Recovery of Degraded Area with Pasture (RDAP), Recovery of Degraded Area with Forest (RDAF), Forest Planting (FP) and Management of Native Forest (MNF). 2,020 properties were supported with the technologies, and 376 species of interest were identified. The RDAF and MNF had the greatest diversity of species group. AFS and RDAP concentrated on one main species, Theobroma cacao and Avena spp. respectively. Thus, it is found a listing of species with potential for projects with different low-carbon technologies in the Atlantic Forest, which are adapted to the local market and with economic and environmental benefits.
Key words: climate change; sustainable rural development; sustainability

INTRODUCTION

The Atlantic Forest is an important biome for Brazil, both for being a biodiversity hotspot and for the economic and social function of the region. It is the most populous biome in the country, with 145 million inhabitants (72% of the population), occupying more than 1.3 million km^2 in 17 states (SOS Mata Atlântica, 2019). Despite this, due to its history of agricultural occupation and expansion, there are still continuous trends of alteration of the original ecosystem, marked by deforestation and the degradation of areas (ALVES-PINTO et al., 2017).

After centuries of exploration, only 12.4% of the native vegetation of this biome remains intact, in the form of small forest fragments isolated in the highly anthropized landscapes (SOS MATA ATLÂNTICA, 2019). Therefore, sustainable land use is essential to overcome many sustainability challenges, rural poverty, food security, water use, ecosystem degradation, loss of biodiversity and climate change (ALVES-PINTO et al., 2017; FAO, 2014).

Rural producers can contribute to food security and mitigate climate change, through forest restoration and the adoption of low-carbon technologies with the sustainable intensification of their production (SAGASTUY and KRAUSE, 2019).

There is a need to disseminate the benefits of low-carbon technologies, such as the provision of ecosystem services, so that investors and decision makers can support projects aimed at implementing those systems on rural properties (SILVA et al., 2018). An example of those projects is the Sustainable Rural, carried out in the Amazon and the Atlantic Forest, with the aim of promoting the adoption of low-carbon technologies, through technical assistance, financial incentives and training for rural producers, selection of species and appropriate technologies (ASSAD et al., 2019).

Although there are several studies on the economic and environmental benefits of low-carbon technologies (CARRER et al., 2020), few report the species implanted in these systems, as a way of directing technical assistants and rural producers at the time of choice.

Thus, the creation of a species database can accelerate the success of these projects, especially when the choice is made by specialists, whose training allows the choice of species under different environmental conditions, increasing the success of programs when selecting most suitable species.

In this sense, species were identified for implantation in different low-carbon technologies in the Atlantic Forest, from trained specialists and rural producers.

MATERIAL AND METHODS

The study area is based on the Phase I Sustainable Rural Project (PRS I) carried out with rural producers in the Brazilian Atlantic Forest biome, in 40 municipalities in four states: Minas Gerais, Bahia, Paraná and Rio Grande do Sul. Details of the project can be checked on the website http://mata-atlantica-amazonia.ruralsustentavel.org/ and in the book by Assad et al. (2019).

One of the actions of the project was to identify, support and financially encourage the implementation of low-carbon technology in properties of small (modules less than or equal to 4) and medium (modules between 4 and 15) rural producers. Fiscal module is a unit of measure, in hectares (ha), which the value is fixed for each municipality, taking into account several factors, such as the type and income of predominant activity and others. The supported technologies were: Agroforestry Systems (AFS); Recovery of Degraded Areas with Pasture (RDAP); Recovery of Degraded Areas with Forest (RDAF); Plantation of Commercial Forests (FP) and; Sustainable Management of Native Forests (MNF). Each producer could choose the technology that would be best for their reality, being able to choose the implementation of more than one.

It contemplated 2,020 properties, and the main species of interest for implementation for each technology (AFS, RDAP, RDAF, FP and MNF) were identified according to the purpose of the producer. This choice was made through a participatory methodology, based on the scientific knowledge of Technical Assistance Agents (TAA) trained in low-carbon technology by the PRS team and the perception of the producer involved. Taking into account their knowledge, local market, resources available on the property for proper management and economic and environmental benefits.

It was made a list of species or group of species with the highest frequency for each technology, then, a chi-square analysis was performed to check the significance through the p-value using the R-software.

RESULTS AND DISCUSSIONS

With the project's actions, 2,488 interventions were carried out with the implementation of the AFS, RDAP, RDAF, FP and MNF technologies. But the total of properties were 2,020, thus, the same producer could implement more than one low-carbon technology in his property, in a total area of 10,010 hectares.

The total number of species chosen in all the five technologies was 376, and the main species or group of species most frequently presented in Table 1, which did not present a significant difference (p-value> 0.05) between them.

Table 1. Main species and purposes for the different technologies of the Atlantic Forest biome.

Technology	Species	Frequency	Purpose	
AFS p-value < 2.2e-16	*Theobroma cacao*	859	Almond	Seed
RDAP p-value < 2.2e-16	*Avena* spp.	203	Dairy Cattle	Pasture
RDAF p-value = 0.08699	*Cedrela* spp.	59	Timber	Protection and PPA recovery
	Inga Mill.	56	Environmental conservation	Reforestation
	Swietenia macrophylla	56	Timber	Protection and PPA recovery
	Theobroma grandiflorum	55	Fruit	Reforestation
	Eucalyptus spp.	54	Timber	-
	Tabebuia spp.	43	Timber	Environmental conservation
	Anadenanthera spp.	40	Timber	Reforestation
	Paubrasilia echinata Lam.	39	Protection and PPA recovery	Timber
	Persea spp.	39	Fruit	Protection and PPA recovery
	Hymenaea courbaril	38	Environmental conservation	Timber
	Spondias mombin L.	38	Fruit	Protection and PPA recovery
FP p-value = 0.1011	*Eucalyptus* spp.	28	Timber	-
	Syzygium aromaticum	17	Seed	Grains
MNF p-value = 0.2019	*Anadenanthera* spp.	38	Beekeeping	Timber
	Eugenia spp.	38	Fruit	Seed
	Campomanesia spp.	36	Fruit	Beekeeping
	Araucaria angustifolia	27	Seed	Fruit
	Ilex paraguariensis	23	Fruit	Timber

In the AFSs, it was verified that cacao (*Theobroma cacao*) was the most representative species, being chosen from 859 properties, for the personal use or trade of the fruit and seed (Table 1). The cultivation of oats (*Avena* spp.) was widely indicated as forage for RDAP, being represented by 203 producers to pastures formation, mainly for dairy cattle.

The cacao tree is generally used in agroforestry systems shaded with other perennial and annual crops, and the fruit, seed or wood can be commercialized (SOMARRIBA and BEER, 2011). This species can store high amounts of carbon in its biomass, and carbon credits can be sold (SOMARRIBA et al., 2013), if the carbon market policy becomes strengthened.

The *Avena* spp. is a species widely used for animal feed, especially in the dry season (winter), as it is an alternative to improve the cattle productivity, mainly in southern Brazil (PEREIRA et al., 2020). Supplementation with oat silage is also an alternative when the pasture dry mass productivity is limited and to conserve pasture conditions in the dry season (BURBANO-MUÑOZ et al., 2018).

The two species most used in FP were eucalypts for timber purposes and the clove tree of India (*Syzygium aromaticum*) for the commercialization of its seeds. In RDAF, the group of significant species was more heterogeneous when compared to other technologies, presenting a greater variety. The purposes were diverse too, including wood and fruit, but the main objective was environmental conservation, recovery and protection of Permanent Preservation Areas (PPA).

As in FP, eucalypts (*Eucalyptus* spp.) were one of the most chosen species in RDAF (Table 1). With the RDAF technology it is possible to restore areas, with the establishment of new forest plantations in an already open, unproductive, and degraded areas (BRANCALION et al., 2014). The mixed planting of native forest species is efficient for the recovery of degraded areas, mainly with regard to the accumulation of biomass and carbon stock (SOUZA et al., 2020).

Cedar and Ipe were also species used by producers to recover degraded areas with FP. In a study in the Atlantic Forest, it was observed that these species *Cedrela fissilis* and *Tabebuia impetiginosa* obtained positive responses to fertilization and pest management, promoting positive impacts on the recovery of degraded areas (CAMPOE et al., 2014). It is important to use forest species for the protection and recovery of headsprings and PPA areas for the environmental regularization of properties, and species such as Ingá and Angico (*Anadenanthera* spp.), can be used to this purpose, mainly because of their rusticity (BAGGIO et al., 2013).

On the other hand, eucalypts can serve as a “savings account” due to the commercialization of wood, because this forest species is capable of producing woody biomass quickly and on a large scale (MCMAHON et al., 2019). *Eucalyptus* productivity in Brazil increased as a result of intensified management, improved cultivation practices and the development of fast-growing genotypes (BINKLEY et al., 2017).

In the MNF, the species that stood out, had the purpose of beekeeping, fruits, seeds and wood. Species such as Angico (*Anadenanthera* spp.) and Guabiroba (*Campomanesia* spp.) were used for beekeeping, and araucaria (*Araucaria angustifolia*) for the extraction of their seeds. Others were fructiferous trees, making economic exploitation by the producer possible through the sustainable management of the native forest (Table 1).

The MNF aims to produce material and immaterial goods constantly and continuously over time, with economic benefits for producers and society, allowing to conserve forests and achieve sustainable exploitation (ANDRAE et al., 2018). *Araucaria angustifolia* was one of the native species most used by the project's producers, which is widely exploited in the states of the southern region of Brazil, due to its excellent technological and ecological value, with the commercialization of its seeds (FIGUEIREDO FILHO et al., 2011).

In addition, in the MNF there is the possibility of the sustainable exploitation of fruit trees, as in the case of *Eugenia brasiliensis*, which allows the commercialization of its fruit (LAZARINI et al., 2018). The availability of food and the sustainable use of natural resources are two inseparable themes in the focus of traditional and contemporary societies. That is why rural producers in some regions of the Atlantic Forest consume and commercialize their native fruits, such as pitanga (*Eugenia* spp.) and guabiroba (*Campomanesia* spp.) (SOUZA et al., 2018).

CONCLUSIONS

It was found 376 species in the 2,488 implanted technologies in more than 10 thousand hectares in the Atlantic Forest biome. It was possible to obtain a list of species with high potential for projects with low-carbon technologies in the Brazilian Atlantic Forest. Those species are adapted to the local market and available for the small and medium producers. When using proper management, those species can bring economical and environmental benefits.

ACKNOWLEDGMENTS

Thanks to the International Climate Fund and the UK Department of Environment and Rural Affairs (Defra), the Ministry of Agriculture, Livestock and Supply (MAPA) of Brazil, the Inter-American Development Bank (BID), the IABS - Brazilian Institute of Development and Sustainability, and to the Brazilian Agricultural Research Corporation (Embrapa) for the composition of the institutional arrangement of the Sustainable Rural Project; to Capes for granting a scholarship to the corresponding author.

REFERENCES

ALVES-PINTO, H. N.; LATAWIEC, A. E.; STRASSBURG, B. B. N.; BARROS, F. S. M.; SANSEVERO, J. B. B.; IRIBARREM, A.; CROUZEILLES, R.; LEMGRUBER, L.; C. RANGEL, M.; SILVA, A. C. P. Reconciling rural development and ecological restoration: Strategies and policy recommendations for the Brazilian Atlantic Forest. **Land Use Policy**, v. 60, p. 419–426, Jan. 2017.

ANDRAE, F. H.; SCHNEIDER, P. R.; DURLO, M. A.; FINGER, C. A. G. Importância do manejo de florestas nativas para a renda da propriedade e abastecimento do mercado madeireiro. **Ciência Florestal**, v. 28, n. 3, p. 1293–1302, out. 2018.

ASSAD, L. T.; MUÑOZ, A. M.; BONET, M. S.; SELVA, G. V. **Projeto rural sustentável fase I: promovendo o desenvolvimento e a agricultura de baixa emissão de carbono na Amazônia e na Mata Atlântica**. Brasília, DF: Editora IABS, 2019.

BAGGIO, A. J.; CARPANEZZI, A. A.; FELIZARI, S. R.; RUFFATO, A. **Recuperação e proteção de nascentes em propriedades rurais de Machadinho, RS**. Colombo: Embrapa Florestas, 2013. 26p.

BINKLEY, D.; CAMPOE, O. C.; ALVARES, C.; CARNEIRO, R. L.; CEGATTA, Í.; STAPE, J. L. The interactions of climate, spacing and genetics on clonal Eucalyptus plantations across Brazil and Uruguay. **Forest Ecology and Management**, v. 405, p. 271–283, dez. 2017.

BRANCALION, P. H. S.; CARDOZO, I. V.; CAMATTA, A.; ARONSON, J.; RODRIGUES, R. R. Cultural Ecosystem Services and Popular Perceptions of the Benefits of an Ecological Restoration Project in the Brazilian Atlantic Forest. **Restoration Ecology**, v. 22, n. 1, p. 65–71, 2014.

BURBANO-MUÑOZ, V. A.; LÓPEZ-GONZÁLEZ, F.; ESTRADA-FLORES, J. G.; SAINZ-SÁNCHEZ, P. A.; ARRIAGA-JORDÁN, C. M. Oat silage for grazing dairy cows in small-scale dairy systems in the highlands of central Mexico. **African Journal of Range & Forage Science**, v. 35, n. 1, p. 63–70, maio 2018.

CAMPOE, O. C.; IANNELLI, C.; STAPE, J. L.; COOK, R. L.; MENDES, J. C. T.; VIVIAN, R. Atlantic Forest tree species responses to silvicultural practices in a degraded pasture restoration plantation: From leaf physiology to survival and initial growth. **Forest Ecology and Management**, v. 313, p. 233–242, fev. 2014.

CARRER, M. J.; MAIA, A. G.; MELLO BRANDÃO VINHOLIS, M.; SOUZA FILHO, H. M. Assessing the effectiveness of rural credit policy on the adoption of integrated crop-livestock systems in Brazil. **Land Use Policy**, v. 92, Mar. 2020.

FAO (Ed.). **Building a common vision for sustainable food and agriculture: principles and approaches**. Rome: Food and Agriculture Organization of the United Nations, 2014.

FIGUEIREDO FILHO, A.; ORELLANA, E.; NASCIMENTO, F.; DIAS, A. N.; INOUE, M. T. Produção de sementes de *Araucaria angustifolia* em plantio e em floresta natural no centro-sul do estado do Paraná. **Floresta**, v. 41, n. 1, abr. 2011.

LAZARINI, J. G.; SARDI, J. DE C. O.; FRANCHIN, M.; NANI, B. D.; FREIRES, I. A.; INFANTE, J.; PASCHOAL, J. A. R.; ALENCAR, S. M.; ROSALEN, P. L. Bioprospection of Eugenia brasiliensis, a Brazilian native fruit, as a source of anti-inflammatory and antibiofilm compounds. **Biomedicine & Pharmacotherapy**, v. 102, p. 132–139, jun. 2018.

MCMAHON, D. E.; VERGÜTZ, L.; VALADARES, S. V.; SILVA, I. R.; JACKSON, R. B. Soil nutrient stocks are maintained over multiple rotations in Brazilian Eucalyptus plantations. **Forest Ecology and Management**, v. 448, p. 364–375, set. 2019.

PEREIRA, F. C.; FILHO, L. C. P. M.; KAZAMA, D. C. S.; JÚNIOR, R. G. Black oat grown with common vetch improves the chemical composition and degradability rate of forage. **Acta Scientiarum. Animal Sciences**, v. 42, jun. 2020.

SAGASTUY, M.; KRAUSE, T. Agroforestry as a Biodiversity Conservation Tool in the Atlantic Forest? Motivations and Limitations for Small-Scale Farmers to Implement Agroforestry Systems in North-Eastern Brazil. **Sustainability**, v. 11, n. 24, Jan. 2019.

SILVA, R. F. B.; BATISTELLA, M.; MORAN, E. F. Regional Socioeconomic Changes Affecting Rural Area Livelihoods and Atlantic Forest Transitions. **Land**, v. 7, n. 4, dez. 2018.

SOMARRIBA, E; CERDA, R.; OROZCO, L.; CIFUENTES, M.; DÁVILA, H.; ESPIN, T.; MAVISOY, H.; ÁVILA G.; ALVARADO, E.; POVEDA, V.; ASTORGA, C.; SAY, E.; DEHEUVELS, O. Carbon stocks and cocoa yields in agroforestry systems of Central America. **Agriculture, Ecosystems & Environment**, v. 173, p. 46–57, 1 jul. 2013.

SOMARRIBA, E.; BEER, J. Productivity of Theobroma cacao agroforestry systems with timber or legume service shade trees. **Agroforestry systems**, v. 81, n. 2, p. 109–121, 2011.

SOS MATA ATLÂNTICA. **A Mata Atlântica, 2019**. Available at: <https://www.sosma.org.br/conheca/mata-atlantica/>. Accessed on: 3 out. 2020.

SOUZA, M. T. P.; AZEVEDO, G. B.; OLIVEIRA SOUSA AZEVEDO, G. T.; TEODORO, L. P. R.; PLASTER, O. B.; ASSUNÇÃO, P. C. G.; TEODORO, P. E. Growth of native forest species in a mixed stand in the Brazilian Savanna. **Forest Ecology and Management**, v. 462, abr. 2020.

SOUZA, R. G. D.; DAN, M. L.; DIAS-GUIMARÃES, M. A.; GUIMARÃES, L. A. O. P.; BRAGA, J. M. A.; SOUZA, R. G. D.; DAN, M. L.; DIAS-GUIMARÃES, M. A.; GUIMARÃES, L. A. O. P.; BRAGA, J. M. A. Fruits of the Brazilian Atlantic Forest: allying biodiversity conservation and food security. **Anais da Academia Brasileira de Ciências**, v. 90, n. 4, p. 3583–3595, dez. 2018.